University of Alberta

DESIGN AND DEVELOPMENT OF A COMPUTERIZED EMERGENCY MEDICAL SERVICES –BASED INJURY SURVEILLANCE SYSTEM

by

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Abstract

Injuries are the leading cause of death for people under the age of 44 and cause more potential years of life lost than any other disease process. To reduce the impact of injuries, injury prevention interventions (including education, enforcement, and engineering solutions) must be designed, targeted, implemented, and evaluated. When injuries do occur, emergency medical services, acute care, and rehabilitation services must be coordinated to better respond to and treat them. Injury surveillance data are required to drive this injury control process. However, accurate, timely, and readily available injury data does not exist in the Province of Alberta, Canada. To address this need, this work outlines the design, development, and implementation of a computerized emergency medical services-based injury surveillance system in conjunction with Strathcona County Emergency Services. A data entry and patient management software program was developed for paramedics and emergency medical technicians (EMTs) to utilize in the field for better documenting injury data. To test the system outlined in this thesis, 338 injury-related patient care reports were retrospectively entered using the software and the resulting data was analyzed. This thesis outlines how the software was developed and examines the data input into the system to determine the patterns of the occurrence of injury in Strathcona County.

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List of Abbreviations

AB	Alberta
ACE	Activity, Cause, Effect codes
ALS	Advanced Life Support
BLS	Basic Life Support
BRIS	Basic Routine Injury Surveillance
BRSC	Body Region Selection Control
BTLS	Basic Trauma Life Support
CDC	Centers for Disease Control and Prevention, Atlanta, Georgia, USA
CDPD	Cellular Digital Packet Data
CIHI	Canadian Institute for Health Information
CQI	Continuous Quality Improvement
DBMS	Database Management System
DCS	Data Collection Software
DEEDS	Data Elements for Emergency Department Systems
DIDP	Dynamic Injury Data Program
DOA	Dead on Arrival
ED	Emergency Department
EKG	Electrocardiogram
EMR	Emergency Medical Responder
EMS	Emergency Medical Services
EMS-ISS	EMS-based Injury Surveillance System
EMT	Emergency Medical Technician
FSG	Fort Saskatchewan General Hospital
GCS	Glasgow Coma Scale
GIS	Geographic Information Systems
GNH	Grey Nuns Hospital
GPS	Global Positioning System
GUI	Graphical User Interface
HL-7	Health Level Seven
ICD-9-CM	International Classification of Disease (Ninth Revision) Clinical Modification
ICU	Intensive Care Unit
ISIS	Injury Surveillance Information System
ISSDM	Injury Surveillance System Data Module
LCDC	Laboratory Centre for Disease Control
MB	Megabytes
MODES	Medically-Oriented Data Entry System
MV	Motor Vehicle
MVC	Motor Vehicle Collision
NCICP	National Centre for Injury Prevention and Control, Ottawa, Canada
NISPP	National Injury Surveillance and Prevention Project
OR	Operating Room
PCR	Patient Care Report
PEM	Patient Encounter Model
PHI	Pre-hospital Index

PVP	Predictive Value Positive
PYLL	Potential Years of Life Lost
RAD	Rapid Application Development
RAH	Royal Alexandra Hospital
RAM	Random Access Memory
RHA	Regional Health Authority
SCES	Strathcona County Emergency Services
SNOMED	Systematized Nomenclature of Human and Veterinary Medicine
SOP	Standard Operating Procedure
ST-1000	Fujitsu Stylistic 1000 Hand-held Computer
STARS	Shock Trauma Air Rescue Society
TKVO	To Keep Vein Open
UAH	University of Alberta Hospitals
VB	Visual BASIC
WCB	Workers' Compensation Board

Chapter 1

The Injury Problem

1.1 The Burden of Injury

An injury is any specific and identifiable bodily impairment or damage that results from an acute exposure to thermal, mechanical, electrical, or chemical energy, or the absence of essentials such as heat and oxygen (Gibson, 1961). Injuries are either intentional (i.e., suicide), or unintentional (i.e., motor vehicle collision). The word injury stems from the Latin word *injuria*; "*in*" means "not" and "*jus*" means "right". Injuries are therefore "not right". Unfortunately, injuries are often viewed as "accidents", a term which implies that they are "freak events" which just happen and cannot be foreseen or prevented; this view inhibits serious examination of factors and events leading to injury (Loimer et al, 1996). Injury researchers, however, believe that injuries are both predictable and preventable. Such a mindset is necessary if the tremendous toll of injuries on the healthcare system and on the population in general is to be reduced.

Injury is one of the most under-recognized public health issues facing the world. Three and a half million people worldwide die every year as the result of injuries (World Health Organization, 1993). It is further estimated that 78 million people worldwide are disabled every year because of injuries (Friedman, 1985). In Canada and the United States, injury is the leading cause of death for people under the age of 44 and causes more potential years of life lost (PYLL) than any other disease process (Baker et al, 1992). In North America, more children over the age of one die from injuries than from cancer, heart disease, respiratory disorders, diabetes, and Acquired Immune Deficiency Syndrome (AIDS) combined (Avard et al, 1989). In the Province of Alberta, there were 1,358 deaths and 31,471 hospitalizations as the result of injury incidents in 1994 resulting in 42,774 potential years of life lost (Injury Prevention Centre, 1996). In Alberta since 1900, the rates of infectious diseases such as tuberculosis have steadily decreased in the province; yet, the rate of injury has remained relatively constant during the same time period.

The toll of injuries is staggering not only in terms of mortality and morbidity but also in terms of monetary cost. The average annual cost in Alberta of automobile collisions alone is $3.55 billion (including both direct and indirect costs) (Alberta Motor Association, 1996). The annual burdon of injury in Canada is $14.3 billion, compared to $13.1 billion for cancer (Moore et al, 1997). Less than one cent is spent on injury research for every dollar spent on injury treatment; yet nine cents is spent on cancer research for every dollar spent treating cancer (Elliot et al, 1996).

1.2 Injury Surveillance and the Injury Data Problem

Injury data are used to monitor trends in the occurrence of injury. By studying the etiology of injury events, it is possible to determine risk factors related to person, place, and time for the occurrence of injury and to direct injury prevention efforts. Primary prevention refers to interventions that prevent an injury from occurring and includes legislative, engineering, and educational interventions. Secondary prevention minimizes the consequences of an injury by ensuring that emergency medical service (EMS) crews and acute care personnel are available, highly trained, and able to treat injuries effectively. Tertiary prevention, or rehabilitation, is aimed at reducing the amount of disability caused by an injury and returning the individual to his or her pre-injury state. The result of integrating and coordinating primary, secondary, and tertiary prevention efforts to reduce the occurrences and impact of injury is known as injury control (Francescutti, 1997). Injury data that is accurate, timely, and readily accessible is necessary to plan, implement, evaluate, and sustain the injury control process. Injury surveillance systems can provide the necessary data.

Epidemiologic surveillance is "the systematic collection, analysis, interpretation, and sharing of health data for the design, implementation, and evaluation of public health programs" (Langmuir, 1963). Epidemiologic (or public health) surveillance is also defined as the "systematic and ongoing assessment of the health of a community" (Teutsch et al, 1994). Comprehensive public health surveillance enhances injury research because surveillance data are disseminated in a timely manner, utilized to support and evaluate prevention and control activities, and provide ongoing monitoring of important health issues (Garrison et al, 1994). Surveillance systems designed to monitor the injury problem can therefore assist injury researchers in the following ways:

- to better estimate the magnitude of the injury problem;
- to determine the etiology (causes) of injury;
- to detect outbreaks or "epidemics" of certain types of injuries;
- to evaluate injury control strategies, programs, and interventions; and
- to facilitate the better planning and coordination of injury control efforts.

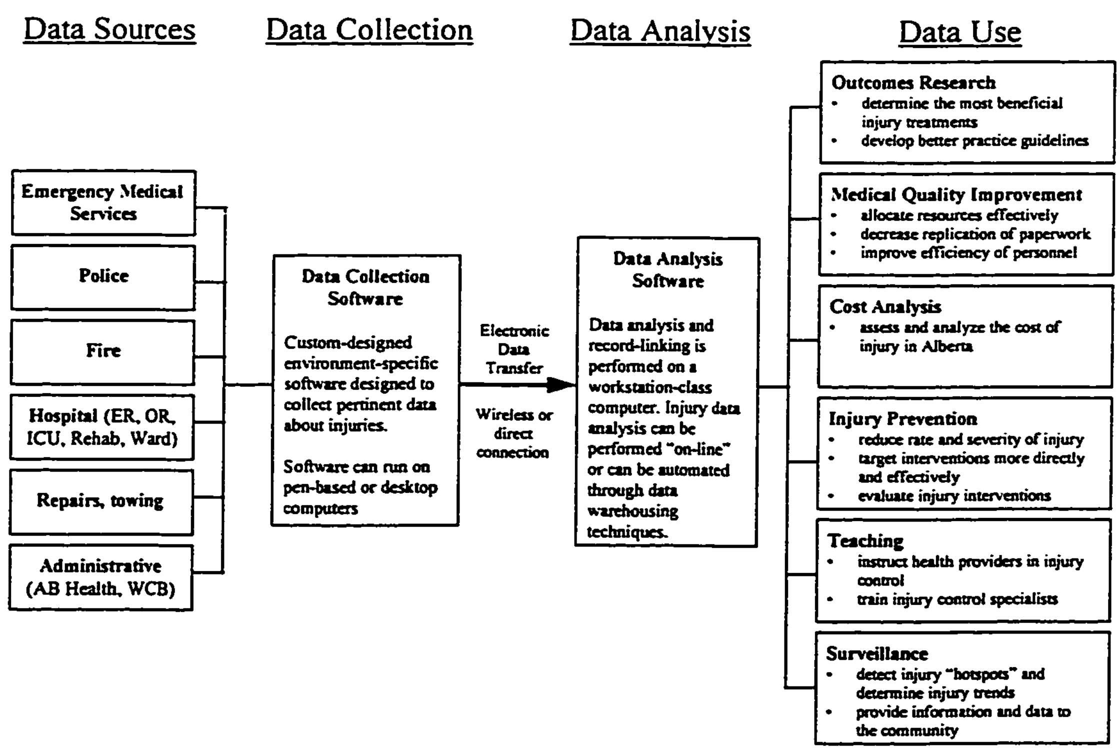
Accurate, timely, and easily accessible data relating to the occurrence and cost of injury in the province of Alberta does not currently exist. The lack of such injury data severely limits the scope, quality, and quantity of injury research that is undertaken. Without proper injury data, it is difficult to target appropriate injury interventions at the risk groups, behaviors, and communities that require intervention. Furthermore, when injury interventions *are* implemented, there is no system in place to efficiently, adequately, and continually assess the effectiveness of those interventions. In Alberta, the *de facto* standard sources for injury data are from provincial government vital statistics and hospital separation administrative databases. Injury mortality data are abstracted from the vital statistics database where as injury morbidity data are abstracted from the hospital separation database. These data sources are designed for administrative purposes, and were not designed to support injury surveillance. Furthermore, mortality and hospitalization data are incapable of capturing all injuries that occur. According to some estimates, for every childhood injury death there are 45 hospitalizations due to injury, as many as 1300 non-hospitalized emergency room visits, and an unknown number of unreported injuries (Gallagher et al, 1984). These numbers suggest a significant under-reporting of injury occurrences in Alberta. Some research shows that injuries that never present to a hospital for admission account for almost 79% of lost productivity six months from time of injury (Waller et al, 1995). Because some research suggests that the most severe injuries (i.e., those that are fatal) differ in kind and nature than less severe and non-fatal injuries (Runyan et al, 1992), injury control personnel may be targeting interventions at groups that are not representative of the entire population at risk for injury. Because currently available injury information in the province of Alberta is inadequate for most serious injury research purposes, there is a strong need for a comprehensive injury surveillance system.

1.3 The Dynamic Injury Data Program

To address the long-standing problems of accuracy, timeliness, and availability of injury data in the province of Alberta, the Dynamic Injury Data Program (DIDP) was initiated to develop, implement, and evaluate a computer-based injury surveillance system. The goal of the program is to provide timely and readily available injury data to the community to aid in developing injury control strategies. The objectives of DIDP are to contribute to the prevention and better management of injuries, to improve our understanding of the impact of injuries on our health care system, to seek trends in injury patterns and to stimulate epidemiological research of injuries, and to identify risk factors associated with injuries.

Injury surveillance modules are being developed for emergency medical services (EMS), hospitals (emergency department, operating room, intensive care unit, wards, and rehabilitation services), police, fire, and administrative sources such as the Workers' Compensation Board. Figure 1.1 is an overview of the Dynamic Injury Data Program. This will permit epidemiologists and other injury control researchers to capture and link injury-related data from a multitude of sources to build a comprehensive picture of how injury outcomes relate to severity, treatment, and rehabilitation. Injury data are to be regularly uploaded to a central data repository, or "server", on which the data are analyzed to determine demographic and etiologic factors and to detect temporal and spatial (i.e., geographic) trends in injury occurrence. Data will be used for outcomes research, medical quality improvement, cost analysis, injury prevention, teaching, and injury surveillance. Analyzed data will be readily available to the community via on-line services such as the internet, or in more traditional formats such as printed reports.

Figure 1.1 Overview of the Dynamic Injury Data Program



1.3.1 Data Sources

The Dynamic Injury Data Program surveillance system is being designed from the ground up to specifically accommodate and link multiple sources of data to ensure a complete and comprehensive database of injury events. The DIDP system will be a modular design allowing for development of individual injury surveillance system modules that are intrinsically compatible and capable of being linked. Each module will be built around a core injury data set and an environment-specific data set. The core injury data set is composed of the basic data elements necessary to conduct injury research. The environment-specific data set is composed of injury- and non-injury-related data elements specific to a particular module. If necessary, custom-designed data collection software can be developed for the different modules using the surveillance data set as the core and using the environment-specific data set as an operational guideline so that the software functions fully in its designated environment. It may not be necessary, however, to develop customized software for each module if injury data can be abstracted from an existing source (i.e., hospital information system). It is more efficient to access existing data with an interface to existing systems than to develop an entirely new system or to modify substantially existing systems. Herrchen et al state, "Data linkage of secondary data sources has some benefits compared to primary data collection. For instance, in our case, we can make more efficient use of information that has already been collected" (Herrchen et al 1997).

The data sets for the Emergency Medical Services (EMS), Emergency Department (ED), Intensive Care Unit (ICU), and Operating Room (OR) modules have been designed. Experts in the respective fields were consulted extensively during the development of the data sets. The EMS data collection and data analysis software systems have been completed and are implemented in 32-bit Windows™ platform. This thesis outlines the development of the EMS system. A prototype system consisting of analysis components for ER, OR, and ICU environments has been implemented on the UNIX operating system. This prototype implementation was developed using the ObjectStore Version 4.0 database management system (DBMS) and written in C++ (Manas, 1997). As the Dynamic Injury Data Program continues to evolve, these existing data sets will be augmented with police, fire, physician, and administrative (i.e., Workers' Compensation Board) modules.

1.4 Scope of Thesis

1.4.1 Epidemiology and Health Informatics

Medical (or health) informatics is the "scientific discipline concerned with the systematic processing of data, information, and knowledge in medicine and health care" (Hasman et al, 1996), and is concerned with the application of information technology to enhance the quality of health care. It is important to note that health informatics does not focus on the computer technology itself, but on how best to acquire, save, manage, and disseminate the information collected (Teich & Waeckerle, 1997). Public health surveillance involves the systematic processing of data and information, and today is becoming increasingly computerized. Therefore, public health surveillance is an ideal field in which to employ health informatics methodology in the design of epidemiologic surveillance systems that deliver scientifically valid and reliable data quickly and accurately.

1.4.2 Goals and Objectives

The goal of this research project is to design, develop, and test the first Dynamic Injury Data Program injury surveillance module – namely, the prehospital EMS-based injury surveillance system.

The objectives of the study are as follows:

1. Develop an injury data set suitable for EMS-based injury surveillance
2. Design and develop software for EMS data collection and data analysis
3. Test the prototype software by retrospectively entering six months of EMS injury-related documentation
4. Based on the retrospective data, investigate the patterns of injuries in the County of Strathcona, our pilot site.

The purpose of this thesis is to document the design and development of a computerized injury surveillance tool that will immediately contribute to injury control efforts in a community and that will form the foundation of and guide future developments into future injury surveillance systems. Furthermore, this thesis commences validation and evaluation of the prototype system through retrospective entry of injury-related EMS data into the newly-designed software and through analysis of the data.

1.5 Organization of Thesis

This thesis is comprised of five chapters, two of which are papers targeted for the medical literature. Chapter 2, "Overview of Injury Surveillance" reviews basic public health surveillance principles, outlines similar injury surveillance efforts around the world, clarifies the differences between trauma registries and injury surveillance systems, and explores what composes an adequate injury surveillance data set. Chapter 3, "First Results from a Computerized Emergency medical Services-Based Injury Surveillance System", is a paper targeted for publication in Annals of Emergency Medicine. Chapter 3 outlines the methodology and results from the first phase of data entry and analysis by elucidating the patterns of the occurrence of injuries to which emergency medical services respond. Chapter 4, "Design and Implementation of an Emergency Medical Services Injury Data Collection and Patient Management Software Program" outlines the development of the data collection software on which the electronic injury surveillance system is based. Chapter 4 is also targeted for publication in Annals of Emergency Medicine. Chapter 5, "Conclusions and Discussion", discusses the implications of this and other injury surveillance systems research, and explores how the system can be expanded, adapted, and improved in the future.

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Chapter 2

Overview of Injury Surveillance

2.1 Introduction to Public Health Surveillance

Public health surveillance is the process of systematically and longitudinally assessing the health of a community or population. Surveillance systems of various forms and levels of sophistication are used by public health researchers to provide the accurate and timely information necessary to develop effective intervention, prevention, and control programs needed to deal with pressing public health issues. Public health surveillance has early roots in the works of John Graunt and William Petty. Graunt's famous book published in 1662, *Natural and Political Observations Made Upon the Bills of Mortality*, is commonly cited as *the* pioneering work in health surveillance. The word "surveillance" stems from the French word *surveiller*, which means the activity of watching over a person or area (Sepulveda et al, 1992). The uses of surveillance systems by public health officials include the detection of epidemics and the tracking of communicable diseases (Teutsch, 1994). Table 2.1 illustrates several uses for public health surveillance systems.

Table 2.1 Uses of public health surveillance systems

To estimate the magnitude of a health problem.
To detect outbreaks or epidemics
To test hypotheses about etiology
To evaluate control strategies
To facilitate planning of interventions and resource allocation

Adapted from Teutsch, 1994.

Public health surveillance is an active and ongoing process consisting of three important steps: data collection, data interpretation and analysis, and dissemination of information and recommendations. Once a public health issue is identified as needing to be monitored, a surveillance system can be implemented to capture data required to define which populations and areas are affected, to detect trends and patterns of its occurrence, and to elucidate risk factors. The information is then synthesized, analyzed, and distributed to persons responsible for the development of prevention and control programs. The surveillance system can then monitor the efficacy and efficiency of the instituted prevention and control programs.

Public health surveillance is an applied science in that surveillance of a public health problem is undertaken with the expectation that prevention and control measures will be developed or that existing measures will be evaluated and improved upon. It is often the case that surveillance results dictate the appropriate action (such as guiding the distribution of immunization shots or identifying the need for emergency medical services). In other cases, however, it is necessary to identify the problem, its associated risk factors, and its mode and rate of spread (if applicable), and to identify appropriate control measures. With appropriately utilized surveillance data it is possible to develop education programs for community-based prevention, to lobby for legislative changes, to suggest engineering solutions, and to identify specific health problems requiring further surveillance and intervention.

2.2 Utilization of Public Health Surveillance Systems

Surveillance systems monitor the occurrence and outcomes of health events such as injury and disease. The information generated from surveillance systems include the frequency of an injury or disease (number of cases, rates, and prevalence); the severity of a condition (case-fatality ratio, mortality rate, hospitalization rate, or disability rate); and the impact of the condition, which can be measured in terms of both long-term and short-term costs. As well, public health surveillance can be utilized to determine risk factors associated with diseases or injuries and to generate hypotheses to guide future research.

Public health surveillance systems are classified as either passive or active (Teutsch, 1994). Passive systems involve health care providers reporting, on a case-by-case basis, occurrences of notifiable diseases. Passive systems are simple and not burdensome to operate, but are limited by variable and incomplete reporting of instances. Active systems, on the other hand, require more researcher involvement through regular contact and outreach to people collecting data regarding certain diseases and injuries. Active systems typically require more resources than passive systems, and thus tend to be utilized only when monitoring situations of particular interest, such as tracking eradication efforts. There are many health issues for which full-scale surveillance systems could be established. However, surveillance systems require resources such as people, time, and equipment for developing and maintaining the system and for analyzing the resulting data. Therefore, it is important to establish the type of surveillance system warranted by the impact of the disease or injury under surveillance.

Since 1992, the Alberta Health budget has been streamlined approximately 15% (Alberta Health, 1998). In light of current health budget restructuring, the health care system is slowly adopting and supporting more preventative- and evidence-based medicine. In order for prevention to be effective, however, it must be based on accurate surveillance information. To ensure optimal utilization of resources, only health events considered "high priority" should be considered for a dedicated surveillance system. There are many factors to be considered when identifying high priority health events (Teutsch, 1994). The criteria for such identification includes the frequency of the health event (incidence, prevalence, mortality, and years of potential life lost), severity of the health event (case-fatality ratio, hospitalization rate, disability rate), and the cost, preventability, and communicability of the health event. These criteria are outlined in Table 2.2. The criteria assist researchers in determining whether the potential for minimizing the impact of a health event or preventing the events altogether warrant the expenditure of scarce research funding.

Table 2.2 Indicators useful for identifying high-priority health events.

- frequency (incidence, prevalence, mortality rate, years of potential life lost (YPLL))
- severity (case-fatality ratio, hospitalization and disability rate)
- costs (direct and indirect)
- preventability
- communicability
- public interest

Adapted from Teutsch, 1994.

2.3 Injury Surveillance Systems Research

Surveillance systems for infectious diseases have existed for decades, monitoring the progression of diseases and aiding the development of prevention programs for populations at risk. Although injuries are a major burden on the health care system, surveillance systems to monitor and control the occurrence of injuries are only in their infancy. As awareness of the predictable and preventable nature of injuries continue to grow, and as injuries are viewed less as "accidents" and "acts of God", efforts to develop injury surveillance systems and injury prevention and control programs are increasing in number and sophistication.

2.3.1 The Surveillance Challenge

Accurate and timely information is the cornerstone for effective injury control efforts. Up to 97% of all injuries that require medical attention, however, are never entered and stored in any comprehensive database for use in injury surveillance systems. This failure to record such a potential wealth of surveillance data in a standardized and easy to access format impedes assessment of a community's health care needs and "limits the ability to scientifically assess the effectiveness of interventions"(Garrison et al, 1994). Most injury data are composed of mortality and hospitalization statistics, although such statistics represent only the "tip of the iceberg". For every childhood injury resulting in death, there are 45 hospitalizations and 1300 Emergency Department (ED) visits (Gallagher et al, 1984). Estimates suggest that up to 25% of all injuries are treated by either a clinic or a physician (Williams et al, 1995) and never reach an ED, (although, potentially, this percentage could be much higher). Furthermore, the impact of an injury spreads beyond the injured person to family, employers, the health care system, and the community (Francescutti et al, 1991). Because the vast majority of injuries do not result in death, injury surveillance based on mortality statistics alone is inadequate. The patterns of occurrence and the associated risk factors are different for fatal and nonfatal injuries (Runyan et al, 1992), and injury surveillance systems must be made sensitive to that fact.

There is a demonstrated need for more comprehensive and sensitive injury surveillance systems. Approximately 80% of all injured persons needing medical attention are cared for at hospital emergency departments (Runyan et al, 1992). Although by no means representative of all injury cases, the large number of injuries that present to EDs suggest that next-generation injury surveillance systems must be more comprehensive in scope and in detail than are current systems. A proposal for a national injury surveillance strategy suggests that further development of ED- and other health provider-based injury surveillance systems is warranted (Garrison et al, 1994). They recommend to further the design and testing of new surveillance systems and to use new and evolving technology to standardize information collection within and among facilities. One suggested goal is the development of a population-based ED injury surveillance system consisting of all EDs serving a community (Garrison et al, 1994). In Canada, there is movement toward the development of a nation-wide trauma registry beginning with the development of a national minimal data set (based on selected hospital discharge data) (McLellan, 1997).

2.4 Design and Development of Injury Surveillance Systems

2.4.1 Injury Surveillance Data Sets

An injury surveillance system can be built upon the techniques and principles of other public health surveillance systems. Factors unique to injury surveillance that must be considered for purposes of accurate injury data collection are defining what an injury is, defining the injured population, and defining the injury data set (Williams et al, 1996). Depending on the setting in which it is used, the word "injury" can be interpreted differently. Injury can be defined as the *outcome*, such as a fractured leg, of an event. An injury can also be defined as the *event* itself, such as a motor vehicle crash. For surveillance and epidemiological purposes, injury as an *event* is the most commonly used definition, although surveillance data most certainly will contain information about the *nature (or type)* of injuries. The criteria on which the case definition is based should match the objectives of the surveillance system.

A truly effective and standardized injury surveillance data set has yet to be developed. A comprehensive injury surveillance data set should contain basic demographic information and include data concerning the type and cause of injury (Williams et al, 1996). This lack of a standard mechanism to obtain information such as incidence, demographics, and type of injury that is necessary for injury surveillance hinders injury research (Williams et al, 1995). Most data sets used by injury researchers are custom-designed for specific research projects and do not collect data in a standardized format; therefore, the data may not be comparable to the data collected by other projects. The Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia, USA, recommends that an injury surveillance system data set contain information about the time, place, person, type of injury, medical care, and the outcome of the patient (Runyan et al, 1992).

A minimum data set for injury surveillance should provide information about the basic epidemiologic elements required for surveillance, including person, place, time, and data about the cause, nature, and outcome of an injury. Graitcer (1991) presents a minimum data set for injury surveillance, which is replicated in Table 2.3.

Table 2.3 Minimum data set for injury surveillance

Person	Age, sex, race, and place of residence of the person injured.
Location	Place where the injury occurred (i.e., home, school, work, ball field).
Time	Date and time when the injury occurred.
Nature of injury	Part(s) of the body injured (i.e., fractured left arm).
Cause of injury	Description of how and why the injury occurred. Use an E-code if possible.
Diagnosis	Specific diagnosis (using ICD-9 N-codes)
Outcome	Outcome of patient following injury (i.e., treated, hospitalized, died)
Other factors	Any other factors impacting the injury (i.e., seat belt / motorcycle helmet use)

From Graitcer, 1991

Australia has been developing surveillance systems for injury control for over a decade (Harrison et al, 1993). In 1986, the National Injury Surveillance and Prevention Project (NISPP) was established and in turn developed the Injury Surveillance Information System (ISIS). The goal of ISIS was to "develop a surveillance instrument which would maximize the potential for primary and secondary prevention of injury" using custom-designed software. ISIS is a stand-alone system with its own specially-designed injury data set. Currently, the Australians are developing their next-generation injury surveillance system based on their experience with ISIS. The National Injury Surveillance Unit, part of the Australian Institute of Health and Welfare, has proposed the Basic Routine Injury Surveillance (BRIS) data set to supercede ISIS. Rather than a stand-alone system, the BRIS data set is designed to be incorporated into commercially-available hospital information systems to foster the wide-spread collection of injury data. Table 2.4 illustrates the BRIS core data items.

Table 2.4 Basic Routine Injury Surveillance (BRIS) core data set items

Type of place of injury event
Type of activity when injured
Event description
Injury: body part and nature of injury
Main external cause of injury

The National Centre for Injury Prevention and Control (NCIPC), a branch of the Centres for Disease Control and Prevention (CDC) has coordinated the development of *Data Elements for Emergency Department Systems (DEEDS)*, currently in its first release (NCIPC, 1997). DEEDS is a recommended data set specification for recording observations, actions, instructions, and conclusions found in emergency department records. DEEDS contains a total of 156 data elements in a total of eight sections. Table 2.5 is a summary of the DEEDS sections. DEEDS is not meant to be established as a minimum data set for coding, but is meant to promote greater uniformity among data elements chosen for administrative and surveillance purposes. The rationale behind DEEDS is to reduce the monetary and time costs of data collection and data linking by encouraging the uniform recording of health information data elements. Congruent with current endeavors to computerize data recording, an objective of DEEDS is "to provide uniform data elements that harmonize with prevailing standards for electronic data entry and exchange."

Table 2.5 Data Elements for Emergency Department Systems (DEEDS) major sections

Section 1	Patient identification data
Section 2	Facility and practitioner identification data
Section 3	ED payment data
Section 4	ED arrival and first assessment data
Section 5	ED history and physical examination data
Section 6	ED procedure and result data
Section 7	ED medication data
Section 8	ED disposition and diagnosis data

The DEEDS data set contains no specific section for injury, but many common injury elements are contained in the ED data sections. Section 5 of DEEDS, the ED history and physical examination data, includes *date & time of injury/illness onset, injury incident description, injury incident location type, injury activity, injury intent, safety equipment use*, and *coded cause of injury*. The *injury incident description* is described in the DEEDS manual as, "a brief description of injury incident that precipitated patient's ED visit", and is recorded as narrative text. The *coded cause of injury* is meant to be coded with an ICD-9-CM E-code (external cause of injury). The other injury-related fields are also designed to be coded and the DEEDS manual includes its recommended coding scheme for these fields.

Data elements should be added to data sets only after careful deliberation as to whether or not the additional information is necessary. As more information is collected by a surveillance system, a more complex, and perhaps expensive, system to operate evolves. In this regard, Williams et al (1996) state, "although one goal of injury control and prevention research is capture of the underlying cause of injury and the existence of co-morbid factors associated with various injury events, this type of information is the most difficult and costly to collect."

2.4.2 Injury Coding for Surveillance Systems

The issue of standardized and systematic coding for data elements in surveillance systems (and in any large database) cannot be over-stated. When comparing information across data sources or when comparing one data set to another, the availability of a standardized and systematic coding system helps assure that the same health events are coded the same way across systems. This is of importance when comparing data from different databases and when extracting and interpreting information from a single database. There are several coding schemes in common use that, while not developed exclusively for injury, are useful when recording information about a patient. The International Classification of Disease (ICD) system is an internationally utilized uniform method of systematically coding the status of human health parameters. The ICD system is beneficial because it removes ambiguity common with narrative and free-text documentation, provides a point of reference for health care researchers, and facilitates data processing and information retrieval. The ICD 9th revision (ICD-9-CM) consists of a classification of diseases and injuries (N-codes), classification of factors influencing health status and contact with health service (V-codes), classification of external causes of injury (E-codes), and classification of medical procedures. Of the classifications, the N- and E-codes are the most pertinent for injury research, and most injury surveillance data sets include at least these two code sets. A new release of the ICD system, ICD-10, will be the new standard for coding at the Canadian Institute for Health Information (CIHI) starting April, 1999.

The lack of standardized injury recording mechanisms in hospital documentation make accurate injury coding very difficult. Most information on ED records is hand-written and in narrative form making it difficult to code and subsequently analyze. For injury surveillance to be accurate, it is vital to obtain detailed and accurate information about the injuries that occur. Hospital documentation contains a wealth of diagnostic information, but diagnostic codes are inadequate for injury prevention studies, for they only code the type of injury - not the cause. For example, using diagnosis codes, it is virtually impossible to retrospectively differentiate between a laceration that is intentional versus one that is unintentional, or that is self-directed versus an assault. Classifying external causes of injury is important for defining injury as a public health problem, identifying and characterizing risk factors, and developing effective prevention strategies (CDC, 1997).

E-codes are important for describing the cause of injury but, unfortunately, E codes are very rarely coded on hospital documentation. The under-utilization of E-codes occurs because medical charts frequently lack enough information to derive E-codes, and patient history narratives by ED physicians are not recorded in a systematic manner that facilitates coding. Ribbeck et al (1992) developed a system for accurately coding E codes prospectively in an Emergency Department setting. A hospital's existing ED interim form was modified to include 62 causes of injury under 12 major mechanism of injury headings. The headings used were transportation, poisoning (drugs, chemicals, gas), falls, sports injuries, firearms, cutting/piercing, assaults, burns, hanging, and other. Using the newly modified form, a triage nurse recorded the cause of injury, chief complaint, vitals signs, and treatment priority. A post-study analysis concluded that the new form did not take any longer to complete than the old form, and that E codes were recorded with an accuracy of 98%. Less than 1% (n=100) of the injuries recorded during the pilot test of this form did not match with an injury on the form, the majority of those (n=49) comprising of a foreign object in an orifice other than the eye. Ribbeck et al promote prospective coding of E codes in the ED environment because, "retrospective review of outpatient records to determine cause of injury frequently results in incomplete data." Medical records often do not contain the information necessary for accurate recording of E codes, and retrospective studies tend to be time-consuming and expensive, and are thus limited to small populations (Ribbeck et al, 1992). The high accuracy rate of the coding of E codes reflects positively the simple, easy-to-follow design of the Mechanism of Injury section of the form. The form developed by Ribbeck and team represents a good starting place to further develop prospective E coding mechanisms for injury surveillance purposes.

The CDC has developed a new matrix with which to present and order ICD-9-CM E-codes (Centers for Disease Control, 1997). The stated purpose of the groupings of external causes is to, "assist persons involved in planning and evaluating injury control programs at national, state, and local levels and are relevant for all persons who collect, code, analyze, and report injury data." The CDC matrix presents the mechanism or cause of injury on one axis, and the manner or intent of the injury event on the other axis. Within each cell of the matrix are contained the appropriate E-codes for particular mechanism and intent "coordinates". The categories within the matrix are mutually exclusive. The major categories of the mechanism/cause axis include are cut/pierce, drowning/submersion, fall, fire/burn, firearm, machinery, MV traffic, pedal cyclist (other), pedestrian (other), transport (other), natural/environmental, overexertion, poisoning, struck by/against, suffocation, other specified (classifiable), other specified (not classifiable), unspecified, and adverse effects. The categories under the manner/intent axis are unintentional, self-directed, assault, undetermined, and other.

Williams et al developed an ED-based injury surveillance system by incorporating the ED log, physicians' billing records, trauma registry, and hospital registration and billing information into one large database from which extraction of useful surveillance information was possible. "Individually, these data sets are of limited use in conducting injury surveillance, because they contain only specific information on a subset of injured patients. However, the linkage of such data sets may enable researchers to obtain more complete information on all ED patients, including those presenting with injuries" (Williams et al, 1996). The authors further note several challenges during development of their ED-based injury surveillance system: 1) defining the injured population, 2) establishing methods to link data sets, 3) assessing and improving the quality of the data, 4) defining the injury data set, 5) working with system personnel, and 6) maintaining the system. They developed an intricate algorithm to derive E codes based on the information contained in several records. Although the algorithm is comprehensive, it is somewhat complex and open to interpretation and error.

2.4.3 Injury Surveillance Versus Trauma Registries

Many hospitals and health regions operate "trauma registries". Trauma registries are intended to collect trauma information from defined groups over time, and are intended to "create data bases on injured patients cared for within a given institution, association, region, or governmental jurisdiction" (Rodenberg, 1996). Trauma registries are most often utilized by large urban trauma centres, and are very often linked with an academic institution. Registries are necessary because, "a summary measure of human trauma is necessary for the scientific study of injury and the evaluation and management of systems that care for injured patients" (Osler et al, 1997). Registry data are intended for use in the prevention or treatment of disease, the provision of care, the study of changing patterns of injury or treatment, and the evaluation and planning of health services (McLennan, 1997). There has been an increase in the number of trauma registries contributing injury-related information for both clinical and administrative purposes (Ehlinger, 1990; Shapiro et al, 1994), and the advent of the microcomputer has certainly expedited the proliferation of such systems (Cales et al, 1985). There are certain problems associated with the exclusive use of registry data for injury research, however. Most registries, operated on personal computers, are "stand alone" systems in that they are not designed to interact with other systems. Because data definitions and coding conventions tend to vary from system to system (thus from institution to institution), data may not be comparable between systems. (Vestrup et al, 1994). For example, different institutions utilize different inclusion criteria (i.e., various injury severity scale scores) for their systems. A serious problem with trauma centre data is that it is not population based, therefore their selected cases cannot relate to less seriously injured or noninjured populations (Committee on Trauma Research, 1985). Only injuries resulting in death and severe trauma tend to be captured by trauma registries; this is only the "tip of the iceberg" with respect to all injury cases. Trauma Registries do not contain sufficient information necessary to determine population-based rates of the incidence of injury (Shapiro et al, 1994). Trauma centre data shows injured populations as being older, more medically impaired, and requiring more frequent hospitalizations, and show more serious head and spinal injuries, fewer fractures to the extremities, and more transportation-related and fewer household-related injuries than nominally occur in the community (Waller et al, 1995). Therefore, the goal of injury surveillance systems is to address the drawbacks of trauma registries by incorporating many sources of injury data, by capturing as many injury cases as possible (which is directly related to the scope of the surveillance "net"), and by promoting community action through dissemination of information to community injury stakeholders.

2.5 Surveillance System Implementation

Once a high-priority health event needing to be under surveillance is identified, there are eight general steps, listed in Table 2.6, through which one should progress to design and develop a successful and effective surveillance system. The first step is to establish the objectives of the system. For example, if injuries are identified to be a high-priority health event, then the objective of a surveillance system might be to monitor the incidence of injuries within a certain community. Step 2, developing case definitions, consists of identifying which populations (or segments of a population) will be eligible for entry into the system. A sample case definition could include all school-aged children presenting to an emergency department as the result of a recreation-related injury. Determining data sources and data-collection mechanisms, step 3, includes identifying current sources of documentation that contain the data of interest such as emergency department logs or school student health records. It is important to note that existing sources of documentation do not constitute a surveillance system *per se* because surveillance is an active process requiring analysis and dissemination of information, where as most currently collected information is not used for purposes of initiating action. Development of data-collection instruments, step 4, consists of designing new documentation to assemble information required for the surveillance system. The preferred method of data collection today is the use of computerized systems. It is important to incorporate standardized coding systems such as the International Classification of Disease (ICD-9-CM) to ensure that data collection is standardized when possible. Patient confidentiality is also an issue, therefore any clear identifiers of individuals must be removed from surveillance documentation. Unfortunately, this may limit the ability to link surveillance data to other systems for supplemental information. Once the data-collection tools have been completed, then the system must be field-tested (step 5) to ensure that errors in collection procedures, system execution, and software (if applicable) are rectified before a large-scale deployment of the system. Identifying and correcting errors before full implementation of the system is less costly both financially and in terms of time than correcting mistakes after full deployment.

Table 2.6 Designing and Planning a Surveillance System

1.	Establish objectives
2.	Develop case definitions
3.	Determine data source or data-collection mechanism (type of system)
4.	Develop data-collection instruments
5.	Field-test methods
6.	Develop and test analytic approach
7.	Develop dissemination mechanism
8.	Assure use of analysis and interpretation

Adapted from Teutsch, 1994.

Step 6 involves determining the proper analytic approaches to the surveillance data to ensure that the data sources and collection process are adequate. Considerations include the type, amount, and detail of the information being collected. Additionally, if the surveillance system will be maintained electronically, the capacity of the hardware such as hard drive storage space and Random Access Memory (RAM) must be sufficient to store the volume of data to be collected. The software packages for data collection and analysis should be deemed able to manage the necessary statistical analysis and data handling.

Developing dissemination mechanisms, step 7, is of vital importance to the objectives of a surveillance system. Once the data from the system has been analyzed and interpreted, the resulting information must be delivered to researchers, policy makers, and interested individuals so that the information can be put to good use for prevention and control efforts. Dissemination includes the creation of regular reports, publication in journals, and presentations. Other newly evolving communications technology, such as the Internet, provide very efficient methods of disseminating information such as designing "home pages" on the World Wide Web, or distributing data via electronic mail ("e-mail").

The final step in designing and planning a surveillance system is to assure the use of analyzed and interpreted information derived from the surveillance data. Surveillance systems are of no utility if the information generated from them is not used. The following section discusses how to evaluate surveillance systems and how to use the results of the evaluation to conduct quality improvement of the system and to ensure that the users of the system are obtaining the quality and type of information they require.

2.6 Evaluation of Surveillance Systems

All too often many hours of work are spent planning, developing, and implementing health care interventions and programs without consideration of how and when to evaluate the programs. Even surveillance systems, a tool with which other programs and interventions are evaluated, must be evaluated to ensure the system is running efficiently and that the surveillance goals and objectives are being met. There are two sets of attributes by which surveillance systems are evaluated. A surveillance system's qualitative attributes are a measure of its simplicity, flexibility, and acceptability. The quantitative attributes of a surveillance system are measured by its sensitivity, predictive value positive, representativeness, timeliness, and cost.

2.6.1 Surveillance System Qualitative Attributes

The three qualities for which a surveillance system should strive are simplicity, flexibility, and acceptability (Klaucke, 1994). Simplicity refers to a system's structure and ease of operation, and can be evaluated from two perspectives: design and size. When examining simplicity, factors include number and type of reporting sources, methods of transmitting case information, training requirements, data analysis methodology, level of computerization, and amount of time to operate the system. Flexibility is the surveillance system's ability to handle new data elements or other, unanticipated requirements of the system. Acceptability is the willingness of other organizations and individuals to participate in or contribute to the surveillance system.

2.6.2 Surveillance System Quantitative Attributes

The quantitative attributes of a surveillance system, sensitivity, predictive value positive, representativeness, and timeliness should be assessed to ensure that the system is operating efficiently (Klaucke, 1994). Sensitivity is an estimate of the proportion of the total number of cases of an injury or disease in a community that is detected by the system, and is determined by comparison with a "gold standard". If no gold standard exists, and sensitivity is being determined through comparison with another surveillance system, the proportion is referred to as "completeness of coverage". As illustrated in Figure 2.1, sensitivity is calculated by dividing the number of events (i.e., injuries) correctly detected by the surveillance system (cell A) by the actual total number of events as reported by the gold standard (cell A + cell C).

Predictive Value Positive (PVP) is the proportion of persons identified as having a condition that actually do have the condition. As per Figure 2.1, is calculated by A/A+B. PVP is an important attribute because a low PVP suggests that there may be unnecessary and inappropriate resource expenditures on interventions as the result of a high number of false positives. Representativeness of a surveillance system is an indication of how accurately the population captured with the system reflects the characteristics of the population at risk for injury. Sources of bias that may affect the representativeness of a surveillance system include case ascertainment bias and information bias. Case ascertainment bias, also known as sampling bias, is caused by the differential identification and reporting of cases of a health event over time or from different populations. Information bias results from errors in the information provided to a surveillance system and include either incorrect or absent data.

Figure 2.1 – Surveillance System Quantitative Evaluation Matrix

		Condition Present / Reported by "Gold Standard"	
		YES	NO
Detected by Surveillance System	YES	True positive **A**	False positive **B**
	NO	False negative **C**	True negative **D**

Sensitivity = A/(A+C)

Predictive Value Positive = A/(A+B)

2.7 Discussion

Injury surveillance as a scientific endeavor is still in its infancy. There is general agreement as to what comprises a good injury surveillance data set, yet work is still necessary to establish a uniform and standardized data set so that comparison and interchangeability of data within and between studies is possible. There is an identified need for injury surveillance systems to support injury control efforts by guiding actions and evaluating interventions. Without injury surveillance systems, injury control initiatives and research will be severely hindered.

Modern computing technology is providing injury researchers unprecedented power for analysis of injury data and to better detect spatial and temporal trends in the occurrence of injury. Future trends in injury surveillance will undoubtedly feature the integration of tools such as geographic information systems, multimedia capable databases, and client-server applications. However the technology might evolve, it is important that researchers do not lose sight of what comprises a truly effective injury surveillance system – a well-defined data set, clear goals and objectives, accurate data, efficient dissemination of information, and continuous system evaluation.

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Chapter 3

First Results from a Computerized Emergency Medical Services-Based Injury Surveillance System

3.1 Introduction

The purpose of this paper is to investigate the patterns of the occurrence of injury in a mixed urban/rural setting as part of the evaluation of a newly-developed emergency medical services (EMS) computerized data collection and analysis system. The computerized system permits researchers to easily describe *who* is getting injured, *where* the injuries are occurring, *when* the injuries are occurring, and *how* they are occurring. With answers to these questions, it is possible to enhance understanding of *why* injuries are occurring, and hence to enact injury control measures to prevent injuries from occurring, or, when injuries do occur, to reduce their severity and long-term impact through coordination of EMS, acute care, and rehabilitation services.

The process of collecting, analyzing, and distributing injury data for the purposes of taking action to reduce the rate and severity of injuries is injury surveillance. The pre-hospital experience of an injured person is perhaps the most neglected source of injury information and data for surveillance purposes. Emergency medical services are an integral part of established trauma systems and EMS is becoming increasingly involved in injury control. EMS personnel are in an ideal situation to actively partake in injury control efforts because of their combined individual health care, public health, and public safety roles. This is possible because EMS systems are widely distributed among the population, they reflect the composition of the community, and they generally enjoy high credibility and status in the community (Garrison et al, 1997). Cognizant of the importance of pre-hospital data for planning and research purposes, researchers and policy-makers have suggested that EMS systems can augment their role in injury control by supporting and promoting the collection and utilization of injury data. Policies should be developed by EMS systems to promote complete documentation of injuries by EMS personnel and to modify data collection tools (including patient care reports) to enhance documentation of injury-specific information, especially about the cause of injury (Garrison et al, 1997).

Injury surveillance systems are not only practical for describing the patterns of injury occurrence, but are useful for outcomes research and quality improvement as well. Although trauma systems have contributed significantly to the decrease in injury-related death and disability, their individual components (including emergency medical services) have not been fully evaluated for effectiveness in the field (Demetriades et al, 1996). The advent of paramedics and highly-trained emergency medical technicians (EMTs) over the last ten to fifteen years has seen great advances in the type and quality of pre-hospital treatment available to patients suffering medical emergencies (Campbell, 1995). Yet, there is little evidence, except in the cases of non-traumatic out-of-hospital cardiac arrest, that advanced EMS interventions have any impact on morbidity and mortality resulting from injury (Spaite et al, 1995). Interestingly, some studies suggest that in large urban areas, private transportation to a trauma centre, or a "load and go" policy for emergency medical services, increases the chances of patient survival from trauma versus more sophisticated advanced life support (ALS) interventions (Demetriades et al, 1996). Even less is known about the efficiency and efficacy of ALS treatment in rural settings, but it is unlikely that the urban results can be generalized to rural settings. Regardless, the "golden hour" begins at the time of *injury*, not the time the patient arrives at the hospital, so when pre-hospital care is available and provided, it is extremely relevant to the eventual outcome of the injured patient. Because of the data requirements for meaningful injury research, any comprehensive injury surveillance system should include pre-hospital data (McLellan, 1997).

To address the concerns of accuracy, timeliness, and availability of injury data within the province of Alberta, the Dynamic Injury Data Program (DIDP) was instituted to design, implement, and evaluate a "next-generation" computerized injury surveillance system. Plans are to develop injury data collection software packages for utilization in the EMS, acute care (i.e., emergency room (ER), operating room (OR), intensive care unit (ICU)), and rehabilitation environments and to link with existing data sources including hospital trauma registries and government health records. The first phase of DIDP development is the design and implementation of an Emergency Medical Services-based Injury Surveillance System (EMS-ISS), and is intended to be the first module of the much larger and comprehensive DIDP injury surveillance system. Although injury-related EMS calls encompass a small subset of the total number of injury occurrences, the EMS-ISS is nonetheless an important and integral part of the evolving larger-scale injury surveillance system.

Computer database systems are becoming more prevalent for some administrative and clinical data analysis applications such as quality improvement and injury impact assessments (Rodenberg, 1996; Smith et al, 1990) and for epidemiological surveillance of injuries (Dean et al, 1994). At best, however, these systems are only partially computerized. Most EMS patient encounter documentation systems that employ computers still extensively rely on paper-based systems for primary data collection; these records are then abstracted and pertinent information is entered into some data system such as a trauma registry. In the Province of Alberta, Canada, standard EMS documentation consists of a single-page, four-copy form called a "patient care report" (PCR). One copy is left behind at the hospital for the health records department, one copy is stored for auditing purposes, one copy is stored in the EMS unit's headquarters for seven years for archival purposes, and one copy is forwarded to Alberta Health (Emergency Health Services

Branch). Certain data elements from the EMS unit's archival PCRs are entered into a computer for administrative and record keeping purposes. Once the government copies arrive at the Emergency Health Services Branch, certain data elements are entered into government computers for analysis and for administrative purposes.

To reduce, if not eliminate, the waste of resources due to data entry redundancy, the data collection tool for EMS-ISS is designed to be used in the field by EMS crews on hand-held pen-based (or "tablet") computers. This data collection software component of the EMS-based injury surveillance system is designed and developed at the Department of Public Health Sciences, Faculty of Medicine and Oral Health Sciences, University of Alberta. Entitled "Medically-Oriented Data Entry System for Emergency Medical Services (MODES-EMS)", it was designed using the Microsoft Visual Basic™ (version 4.0) development environment, and later recompiled on Visual Basic™ version 5.0. The software runs on any Microsoft Windows 95™ compatible hardware platform, including laptops and "tablet-style" computers. Our software was tested in the field on the Fujitsu Stylistic™ line of pen computers.

Because the software is designed for quick and efficient operation in the field, the software is programmed to take advantage of the features such as handwriting recognition offered on hand-held pen-based computers. The graphical user interface is designed specifically for use on tablet-style computers and liberally features check-boxes, pick-lists, icons, and pictures to standardize, codify, and automate data entry whenever possible.

The standard PCR contains very little injury-specific information; all information aside from basic patient demographics is left to the paramedic or EMT to include in his or her free-text narrative of the event. By incorporating all PCR-required data elements into the computer program, the paramedic or EMT is provided a computer on which to document EMS calls which, when appropriate, prompts for specific injury-related information. The MODES-EMS data collection software is designed to accommodate all fields found on the paper-based PCR to ensure compatibility with existing administrative data requirements. The administrative fields include everything from basic patient demographic information to billing information. Many of these fields are unnecessary for injury surveillance purposes. For University of Alberta ethics approval for this pilot project, data to be used in the study was required to be void of any and all information that could be used to identify an individual. When the system becomes operational and is being used the field, all data uploaded for injury surveillance and research purposes will be stripped of personal information.

3.2 Purpose

This paper is a descriptive study of the injury occurrences in Strathcona County between July 01, 1997 and December 31, 1997 for which emergency medical services response was requested (i.e., resulting from a "911" call). This paper is part of a larger study in which a computerized injury data system was designed, developed, and implemented (see Chapter 4). The purpose of this paper is to demonstrate the utility of EMS-based data in an injury surveillance system. To that end, this paper investigates who requests/requires EMS services as the result of an injury event, what the injury events and nature of the injuries are, and where the injuries are occurring, in Strathcona County, Alberta, Canada.

3.3 Methods

3.3.1 Study Population

The purpose of this paper is to investigate the patterns of injury in Strathcona County. The county, a district immediately east of Edmonton, Alberta, Canada, is Alberta's third largest municipality by population. Strathcona County consists of a municipality, Sherwood Park, and a large rural area; the county encompasses a total area of approximately 700 km^2. The population of the county (1996 statistics) is 64,176; 41,989 (65%) live in Sherwood Park and 22,187 (35%) live in the surrounding rural areas. Table 3.1 shows the population breakdown by age and region of residence. Strathcona County is serviced by a single municipally-funded emergency services department (Strathcona County Emergency Services (SCES)). There are 48 paid core EMS personnel and 75 volunteer EMS personnel. SCES core personnel are cross-trained firefighter/EMTs or firefighter/paramedics, and the volunteers are trained to at least first responder level. All ambulances are dispatched from one of five central bases (fire stations) around the county.

Table 3.1 Strathcona County population by age and geographic area.

AGE GROUP	Sherwood Park	Rural	Total
0-24 years	15,808	8,499	24,308
25-44 years	13,130	7,144	20,274
45-64 years	8,717	5,092	13,809
65+	1,878	1,114	2,992
Median Age	*32*	*34*	*33*

3.3.2 Inclusion Criteria

The inclusion criteria for entry into the data system was the occurrence of any injury event to which Strathcona County Emergency Services (SCES) responded between July 01, 1997 and December 31, 1997. For an EMS response to be considered for inclusion in the injury surveillance system, EMS activation must have been due to an incident in which the occurrence of an injury is either the primary or secondary complaint. An example of an injury as a primary complaint is a broken leg due to a fall caused by slipping on ice. An example of an injury secondary to another health event is a broken leg due to a fall caused by loss of consciousness during an MI. EMS responses due to non-injury related events (i.e., seizure with no resulting injury) were not entered into the system. EMS activation is possible by dialing "911" for ambulance dispatch or through a "still alarm" in which a patient presents to the fire station for assessment and possible treatment/transport by EMS crews. There was no restriction as to the age or gender of patients entered into the system, and inclusion was not restricted to people who lived in the county. Cases matched one of three possible outcomes: transport (i.e., transport to hospital or other care facility), no transport (patient transferred to air ambulance; patient refused transport to hospital), and obvious death on EMS arrival to an injury scene. All injury patients for whom a patient care report was written, whether or not they were transported, were included. During the study's time period, there were a total of 1100 ambulance calls of which 338, or 31%, fit the inclusion criteria.

3.3.3 Data Collection

Data was entered retrospectively for this project. Government regulations state that all patient care reports must be saved for seven years. For this investigation, all patient care reports in the archives that were written between July 1, 1997 and December 31, 1997 were viewed. Each patient care report meeting the inclusion criteria was examined further and abstracted. All records were examined, abstracted, and entered into the computer by the author (T.S.) in order to facilitate consistency in data entry. Administrative information was recorded directly from the appropriate fields on the patient care report form, and assessment and treatment information was extracted from the patient encounter narrative. Data for this investigation was entered into the MODES-EMS software program. Fifty records were entered into the software on a Fujitsu Stylistic™ 1000 stylus-based computer, and 288 records were entered into the software on a Toshiba™ Satellite Pro Laptop computer for a total of 338 records. Both computers were running the Windows 95™ operating system with 16 megabytes (MB) of Random Access Memory (RAM). The hand-held computer was equipped with a 320MB hard drive and the laptop had a 540MB hard drive. MODES-EMS operates identically on both systems with the only difference being that data entry is accomplished by using the mouse and keyboard on the laptop and by using the pen stylus exclusively on the hand-held computer. Data entry was split between the two systems in order to test the user-interface under both environments.

By abstracting the PCR narrative and entering pertinent data into the software, it is possible to code assessments, treatments, and other aspects of patient care for later analysis. Table 3.2 illustrates the data variables collected for the purposes of this investigation. Although the MODES-EMS™ program records many more administrative and clinical variables than are listed in Table 3.2, this subset of variables captures the most relevant injury-related variables for data analysis and injury surveillance purposes.

Table 3.2 Data variables collected for purposes of this study

Demographics	gender, age, weight, geographic location ambulance response
EMS Response	time of: dispatch, arrive on scene, depart from scene, arrive at hospital; hospital name; response level (ALS,BLS,EMR)
Medical History	chief complaint, previous medical history, allergies, medic alerts, current medications
Injury Circumstances	type of activity when injured, description of event, external cause of injury (ICD-9-CM E-code), safety devices used, outcome
Injury Assessment	body part injured, nature of injury
Treatment Information	body part treated, nature of treatment

3.4 Results

3.4.1 Population Demographics

There were a total of 338 injury patients entered into the system for this investigation, for which a demographics summary is provided in Table 3.3. There were 199 (59%) males, and 139 (41%) females; this breakdown is similar to the provincial injury hospitalization demographic statistics, which shows approximately 56% males and 44% females (Injury Prevention Centre, 1996). The average ages for males and females were 32.9 years and 41.3 years respectively. A t-test was performed and the difference between the two mean ages was found to be significantly different (two tail, df=336, $p<0.05$). Only two out of 338 ages where unknown because they were not documented on the PCRs.

Table 3.3 Study population demographics

	n	%	Mean Age	Std. Deviation	Variance
Male	199	59%	32.9	23.7	562.6
Female	139	41%	41.3	24.5	599.5
Total	**338**	**100%**	**36.4**	**24.4**	**593.4**

Figure 3.1 and Figure 3.2 illustrate the number of injuries by age group and the number of injuries by age group and gender, respectively. The greatest number of injuries occurred to those between the ages of 15 to 24 (n=77, 22%) and almost two thirds of the injuries in this study population occurred to those under the age of 44 (n=218, 64%). In all age groups, except for 65+, did the number of injuries to males equal or exceed the number of injuries to females.

3.4.2 Causes of Injury

The MODES-EMS software utilizes ICD-9-CM E-codes (external cause of injury) for coding causes of injury. The software uses an adaptation of the CDC's suggested matrix for presenting E-codes (CDC, 1997). The CDC matrix presents the mechanism or cause of injury on one axis, and the manner or intent of the injury event on the other axis. Within each cell of the matrix are contained the appropriate E-codes for particular mechanism and intent "coordinates". In MODES-EMS, by choosing one selection from each of the matrix's two axes the appropriate subset of E-codes is presented from which the user can select the most appropriate entry. The selected mechanism, manner, and E-code entry itself are then all stored in the database.

For purposes of this investigation, causes of injury were grouped according to their major E-code group mechanism/cause category (i.e., motor vehicle collision), and not presented according to actual E-code. This is to eliminate small or null cell sizes in the cause and intent matrix and therefore facilitates more efficient data analysis. Motor vehicle collisions (MVCs) represent all injuries involving motor vehicles, including vehicle-vs-pedestrian and vehicle-vs-bicycle injuries. Falls include all injuries caused by either falling from a height (i.e., off scaffolding), or falling from the same height (i.e., trip or slip). The struck by / against category reflects blunt injuries. The poison category includes any potentially toxic substance including medications, street drugs, and alcohol whose ingestion required EMS response. Overexertion injuries are those injuries caused by pushing the body beyond its limits (i.e., lifting something too heavy). Machinery, cut/pierce, choking, burn, and suffocation causes of injury are self explanatory. Transport (other) includes injuries resulting from use of a vehicle other than a car or truck (i.e., boat).

Table 3.3 outlines the causes of injury in this study population. Over three-quarters of all the injuries were caused by motor vehicle collisions (MVCs) or falls (n=257, 76%). Females in this population suffered more poisoning- and cut/pierce-related injuries than men, but did not suffer any machinery-related injuries at all. There were no males who suffered burn injuries in this investigation's population.

3.4.3 Activity at Time of Injury

Activity at time of injury documents the primary activity at the time of the injury event, or the intent (i.e., self-inflicted or assault) of the injury-causing action. The transportation category includes all injuries in which a person was commuting, including going to or returning from work. Home activity is essentially a "catch all" for injuries occurring in the home, and includes home cleaning/repairing activity, eating, or other home-related activities (not including home-office activities, which would be classified under occupational injuries). The occupational category reflects all work-related injuries, and includes MVC injuries if the primary activity was work-related (i.e., driving a tractor-trailer) as opposed to a commute. The recreation category includes all activity engaged in for recreational purposes (i.e., walking, riding a bike), but does not include injuries from organized sporting competition (i.e., hockey, soccer) which are included in the sports category. Self-inflicted and assault reflect whether the injury was intentionally caused by the patient or another person, respectively. Medication errors reflect poisonings that occurred primarily because the patient was (unintentionally) administered either the wrong medication or the wrong dose of the proper medication.

Three-quarters of the activities at time of injury were transportation- and home activity-, and occupational-related (n=255, 75%). This loosely approximates the high number of MVC and fall causes of injury. Combined together, sports- and recreation-related activities would be the third leading activity at time of injury (n=48, 14%), ahead of occupational-related.

3.4.4 Injury Deaths

Out of 338 injuries in this study, a total of six individuals died either at the scene (apparent death on arrival (DOA)) or were declared deceased upon arrival at hospital. Table 3.4 is the breakdown of the deaths by cause. This results in an injury death rate of 1.8% (6/338) in the population of this study. Our finding of 1.8% of injury cases resulting in immediate death is similar to other findings that report results for rural trauma death (Morrisey et al, 1996).

Table 3.4 – Injury Deaths in the Strathcona County

Cause of Death	**n**
Motor vehicle collision	4
Suicide	2
Total:	**6**

3.4.5 EMS Response Analysis

EMS documentation currently in use does not explicitly call for the *actual* date and time of the event to which EMS is responding. Because the EMS documentation on which this investigation is based rarely recorded the *actual* time and date of injury, the time and date of the EMS *response* serves as a proxy measure. The assumption in this case is that the EMS system was activated almost immediately after the injury occurred. In a few cases, however, this was not the case; sometimes EMS was called up to a couple of hours after the injury event.

The number of EMS responses to injury situations per month are shown in Figure 3.7. The most injuries occurred during the month of July (n=61, 20%) while the fewest occurred during December (n=53, 16%). Although there appears to be a trend of decreasing number of injuries from July until December, there is no statistically significant trend (Chi-square goodness-of-fit, $\chi^2 = 0.769$, p=0.979). Figure 3.8, the number of EMS responses to injury situations by day of week, show that Wednesday (n=73) and Sunday (n=61) have the highest number of calls. While statistical tests indicate that this pattern may not be due entirely to chance (Chi square goodness-of-fit, $\chi^2 = 28.444$, $p<0.05$), further investigation is necessary to determine whether this is an actual trend, and if so, what the risk factors associated with it are. Figure 3.9 shows the number of EMS responses to injury situations by time of day. Almost three quarters (n=243, 72%) of EMS responses occurred between noon and midnight, with just over one quarter (n=95, 28%) occurring between midnight and noon.

Figure 3.10 illustrates the number of EMS transports by destination. Over two thirds (n=231, 68%) of EMS calls ended up in transport to either the University of Alberta Hospital (UAH) or the Grey Nuns Hospital (GNH). There were 51 (15%) calls in which the was not transported to hospital (either because the patient refused transport, or was dead on scene), and 7 calls (2%) were transferred to the Shock Trauma Air Rescue Society (STARS) helicopter air-ambulance. The remaining 49 calls (14%) were transported to either the Royal Alexandra Hospital (RAH), Fort Saskatchewan General Hospital (FSG), or to another location.

3.4.6 Injury Location Analysis

Not only is the software able to capture the cause of injury and the activity at time of injury, but is also able to capture to which body region the injury occurred. Each of these injuries is termed a "discrete" injury. For example, if a patient had a lacerated forearm and a fractured femur, each of those injuries would be classified as a discrete injury. The main body regions as broken down by the software are head and neck (not including c-spine), back, chest, abdomen, pelvis, and extremities. Table 3.5 illustrates the breakdown of number of discrete injuries by body region. There were a high number of injuries to the head and neck (n=176, 31%), extremities (n=225, 40%), and back (n=76, 13%). The remaining 16% (n=88) discrete injuries were injuries either to the chest, abdomen, or pelvis. Table 3.6 illustrates the discrete injury locations for the extremities.

Table 3.5 Discrete injury location - by body region

Region	n	%
Head & Neck (not including C-Spine)	176	31%
Back	76	13%
Chest	45	8%
Abdomen	21	4%
Pelvis	22	4%
Extremities	225	40%
Total	**565**	**100%**

Table 3.6 Discrete injury location - extremities

Region	n	% (n/225)
Arms		
Shoulder	35	16%
Hand	32	14%
Elbow	18	8%
Forearm	15	6%
Upper Arm	6	3%
Legs		
Knee	40	18%
Lower Leg	25	11%
Upper Leg	19	8%
Ankle	11	5%
Foot	5	2%
Total	**225**	**100%**

3.4.7 Response Time Analysis

Table 3.7 illustrates an analysis of the time frame in which the ambulance calls take place. *Dispatch* is the time between which a 911 emergency call was made and when the ambulance left the fire station. The average dispatch time was 1.28 minutes. *Response* is the time between which the ambulance leaves the fire station and arrives on scene. The average response time for this investigation was 6.18 minutes for the crew to arrive at the scene of an injury. *On scene* is the time the EMS crew spent at the scene. In this study, the average time on scene was 9.24 minutes. *Transport* time is the time to get from the scene to the final destination (i.e., hospital). It took an average of 22.2 minutes for the crews to reach the final destination from the scene of an injury.

Table 3.7 Response Time Analysis

Time	n	mean	median	SD	minimum	maximum
Dispatch	338	1.28	1	2.35	0	31
Response	337	6.18	4	5.17	0	29
On-scene	332	19.30	18	9.24	2	60
Transport	278	22.21	21	7.78	9	53

It is important to note some considerations with the EMS time analysis. High values for "dispatch" (i.e., 31 minutes) reflect the few calls in which a second ambulance was requested by the first EMS crew arriving on scene due to a multiple casualty situation. In these cases, the time of the original 911 call is recorded, not the time the request was received for a backup ambulance. For still alarms, or calls in which the patient presents to the fire station, the time call received, time of dispatch, and time of arrival on scene will be recorded as the same time. In the cases of still alarms, then, the "response" time will be zero minutes. Short "on-scene" times (i.e., 2 minutes) result when a second ambulance is dispatched after the first crew arrives on scene. Upon arrival, the second ambulance is loaded with the most critical patient(s) and transported directly to the hospital while the first ambulance continues to assess and treat less critical patients. Conversely, long on-scene times reflect ambulances that respond first and stay on-scene longer while the most critical patients are transported by the second ambulance; it can also reflect time for difficult extrications or rescues. "Transport" time is affected by whether or not the patient is transported via emergency traffic (i.e., "lights and siren") or normal traffic; long transport times can also reflect the long distance between some rural response locations and the final destination.

3.5 Discussion

Health care in the Province of Alberta has seen budgets reduced significantly over the past few years. Therefore, in order to reduce costs associated with health services, evaluation of the efficiency of such services must be performed. Reviews and evaluations of air ambulance services with respect to necessity of transport and quality of care have been conducted. For example, examination of air ambulance services revealed that air transport of trauma patients in urban settings does not decrease the time between injury occurrence and arrival at trauma centre as compared to ground transport, and that there is no advantage to using an air ambulance in urban settings where efficient ground-based pre-hospital care services exist (Norton et al, 1996).

As opposed to numerous studies on urban trauma systems including air ambulance services, there is surprisingly little literature with respect to the quality and types of services offered by rural EMS systems (Morrisey et al, 1996). This paper attempts to address this gap in the literature. The results from this investigation are not surprising. The demographics breakdown is similar to that of provincial injury hospitalization demographics. The causes of injury in this investigation generally reflect the trends for the province of Alberta. As expected for a rural population, there was a very low injury death rate, few assaults or violence-related injuries, and no gunshot injuries. Although the results from this investigation are not unexpected and generally reflect the overall picture of injury in the province of Alberta, it is important not to generalize our results too broadly. It is unlikely that these results closely reflect urban patterns of injury.

3.5.1 Sources of Bias and Error in the Data

MODES-EMS attempts to control the accuracy and the validity of data entered into the system to ensure the highest possible quality of data for the research and administration purposes.

By providing check boxes, pick-lists, and a controlled vocabulary, computer software for special-purpose data entry can vastly improve the quality of the data with respect to consistency, accessibility, and legibility. However, the information generated by the computerized system is only as good as the data that is input into the system. There are several possible sources of bias and error in the data utilized for this investigation. Bias and error can be external to the computer program or related to the computer program. Bias and error sources external to the computer program include selection bias, inaccuracies in EMS documentation due to recall bias and attention to detail. Sources within the program contributing to bias and error include how the data are stored and what selections are available to the EMS crews using the software.

One possible source of bias in the data that might impact on the generalizability of the findings is selection bias. EMS activation is highly determined by the tolerances and attitudes of the individual activating EMS services (either the injured patient or bystanders at the injury scene). Studies have shown that even in locations with a free ambulance service, up to 16% of badly injured patients (injury severity score > 15) make their own way to the hospital via car, taxi, or other mode of transportation (McNicholl et al, 1995). This underscores the point that it is important to expand the scope of the injury surveillance system so that as many injuries as possible are entered into a system. Otherwise, the data generated from scattered efforts may not be generalizable or even representative of the population under surveillance.

Another possible external source of bias and error is the quality of the documentation. In a retrospective study such as this, the PCR is the only source of information – therefore, the quality of the PCR impacts the quality of the data for the study. There are several possible sources of error with the data. It is possible that recall bias, especially with respect to recapping one's previous medial history, may affect the accuracy of the documented information. It may be that patients may not remember pertinent medical history such as operations or diseases, or that patients may not wish to divulge certain aspects of one's history. For example, although not part of the data analysis presented here, analysis of the previous medical history and current medications of the patient reveal that more patients reporting use of anxiolytic and antidepressant medications than reported anxiety and depression as medical history. This is only a very tentative finding, and the data will need to be analyzed further.

Although the nature of the injury is important for injury surveillance, information contained within the narrative of the PCR usually contains insight as to how the injury occurred (i.e., via a description of a car crash or events leading up to an injury event). However, the quality of this information may be limited by the patient's ability to recall the event, the presence of any bystanders if the patient is unconscious or unable to recall the event, and the attention to detail by the EMS crewmember while documenting injury events. A concept to be implemented in the next phase of the project is to equip EMS crews with a digital camera for taking photographs of an injury scene to augment standard documentation practices. Other studies investigating the use of cameras by EMS crews are encouraging. For example, Hunt et al (1996) report a study of EMS crews using an instant camera for recording motor vehicle crash damage. They report that out of 290 photographs, EMTs were able to determine both the severity and damage resulting from the crash in 92.5% of the photos and were unable to determine both area and severity of damage in less than 1% of crash photographs. The ability to augment recorded data with photographic evidence is a promising technique for ensuring that useful information is collected.

3.5.2 Conclusions

Our research to this point has demonstrated that a computerized system can be developed for recording injury data in an EMS environment that is potentially useful for injury surveillance purposes. It is important, however, to develop other injury data modules to link the EMS surveillance data with that of hospitals, other medical centres, rehabilitation centres, and even physicians' private offices. Only then will a truly accurate and comprehensive understanding of how injuries impact society be possible. The lessons learned from this pilot study will help guide the way to future developments.

The next step for this project is to fully implement the software system at SCES so that all EMS crews are trained to use the system. Once the system is fully implemented, the collection of prospective injury surveillance data and near-real-time tracking of injury occurrences will be possible. As the system is being implemented, more thorough system evaluations will be conducted. The system will be evaluated for qualitative attributes including its simplicity, flexibility, and acceptability. The accuracy, validity, reliability, and representativeness of the resulting data will be determined, as well (although this will prove to be a challenge because the baseline data, based on mortality records and hospitalization data, is not an accurate picture of the injury problem).

The potential of this type of computerized system is only just being realized. As future modules of the system are developed, the accurate, timely, and readily available injury data that is produced will surely improve the quality and quantity of meaningful injury research being conducted. This EMS based system is only the first step in the development of a fully integrated injury surveillance system. As the EMS system grows and as other modules are developed, it is hoped that the administrative infrastructure be developed to support injury research and that injury control interventions based on surveillance findings be adopted to reduce the rate of the occurrence of injury in the Province of Alberta.

Figure 3.1 – Number of injuries – by age group

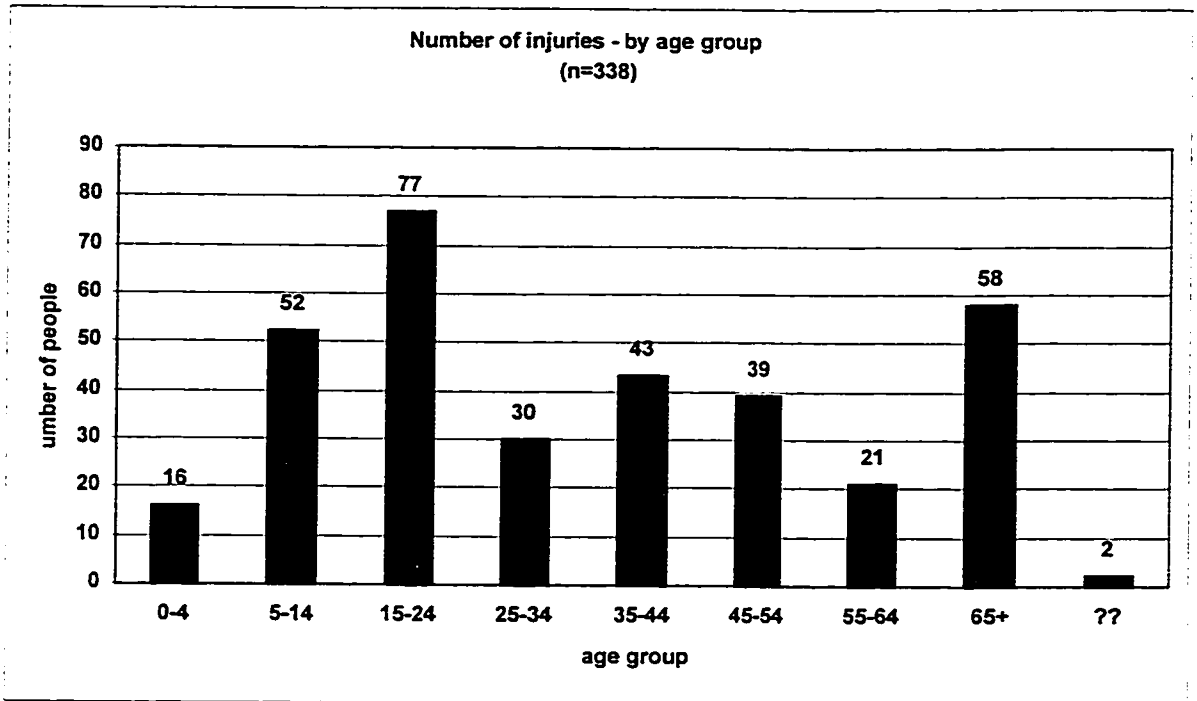


Figure 3.2 – Number of injuries – by age group and gender

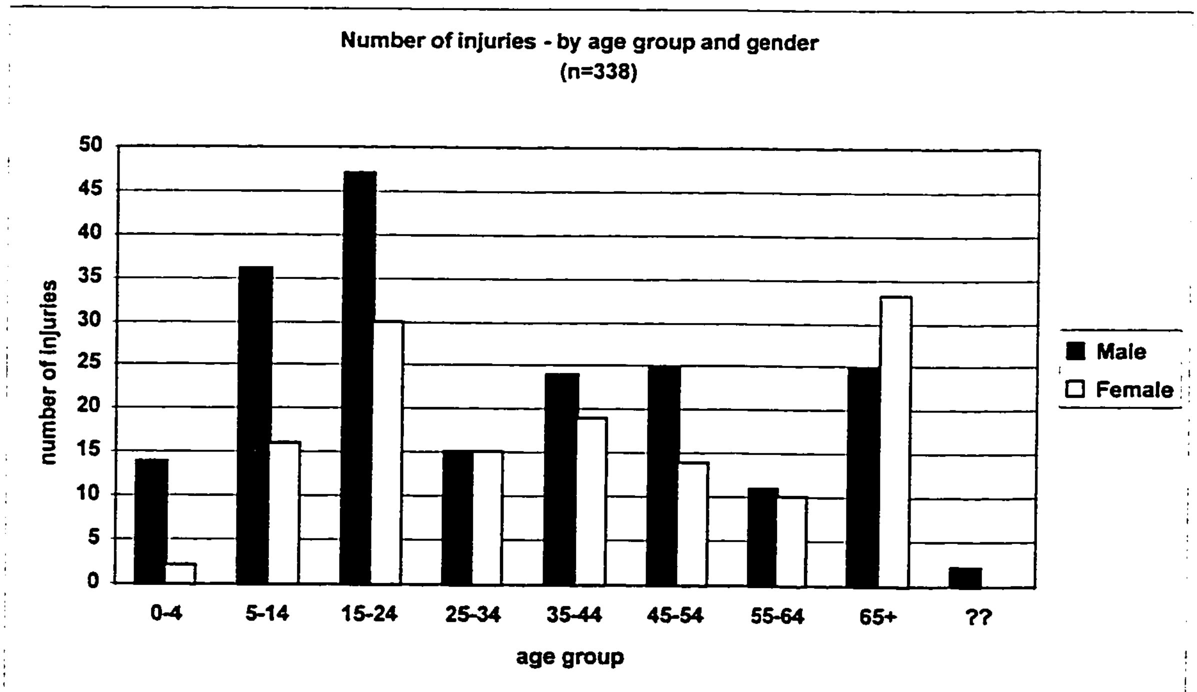


Figure 3.3 – Causes of injury

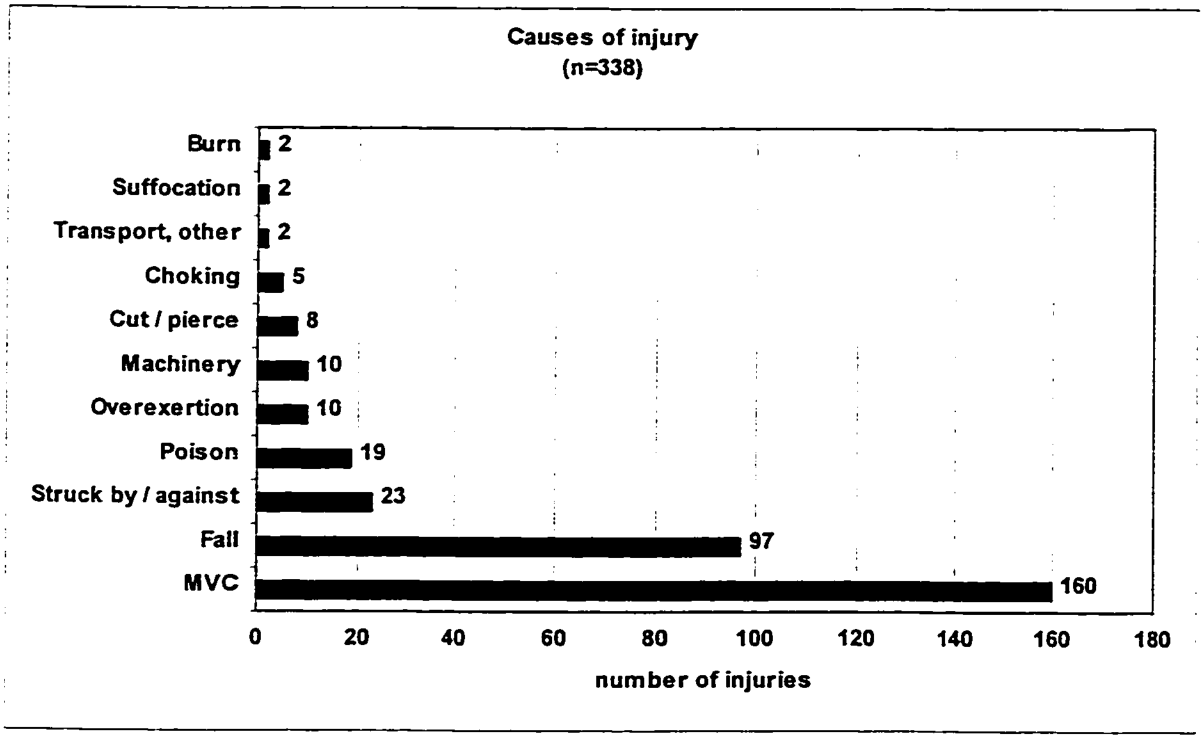


Figure 3.4 – Causes of injury – by gender

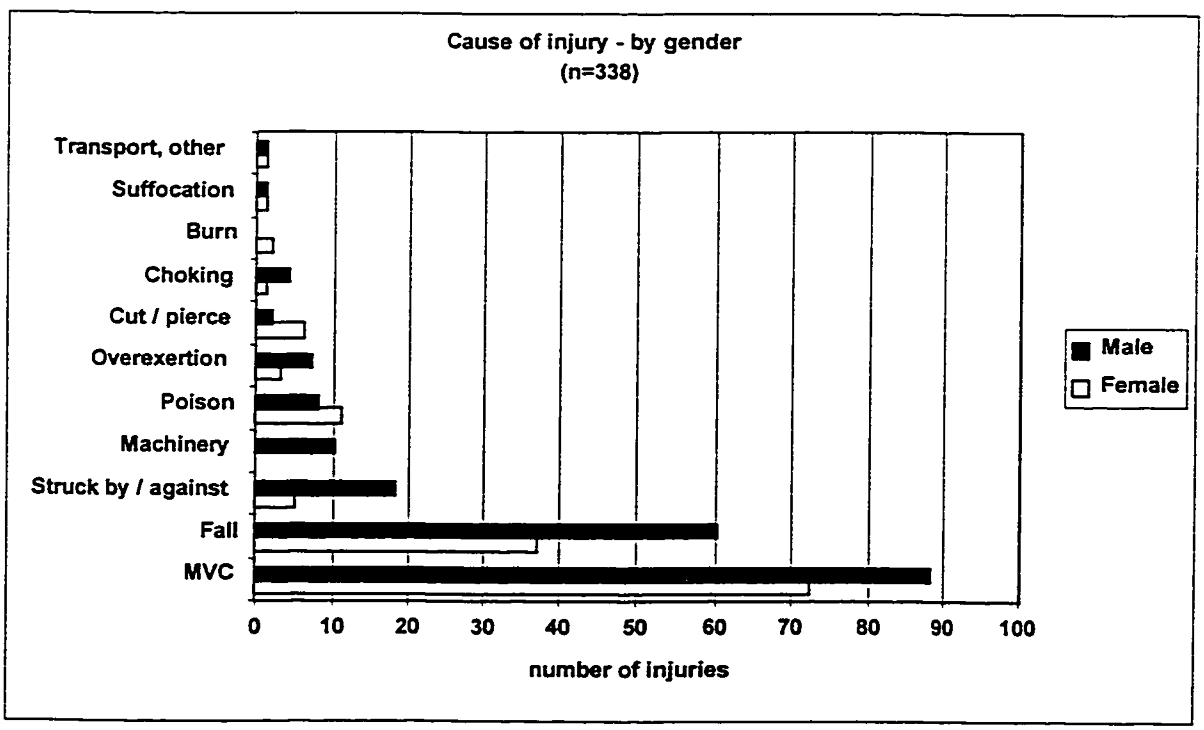


Figure 3.5 – Activity at time of injury

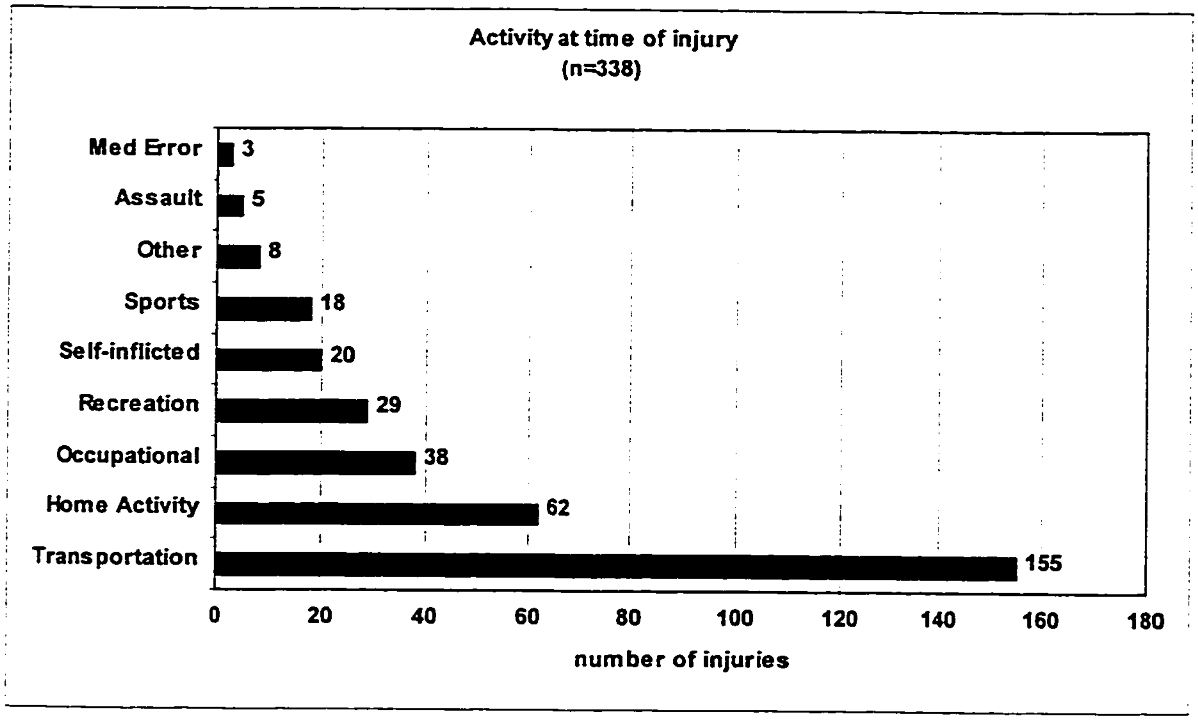


Figure 3.6 – Activity at time of injury – by gender

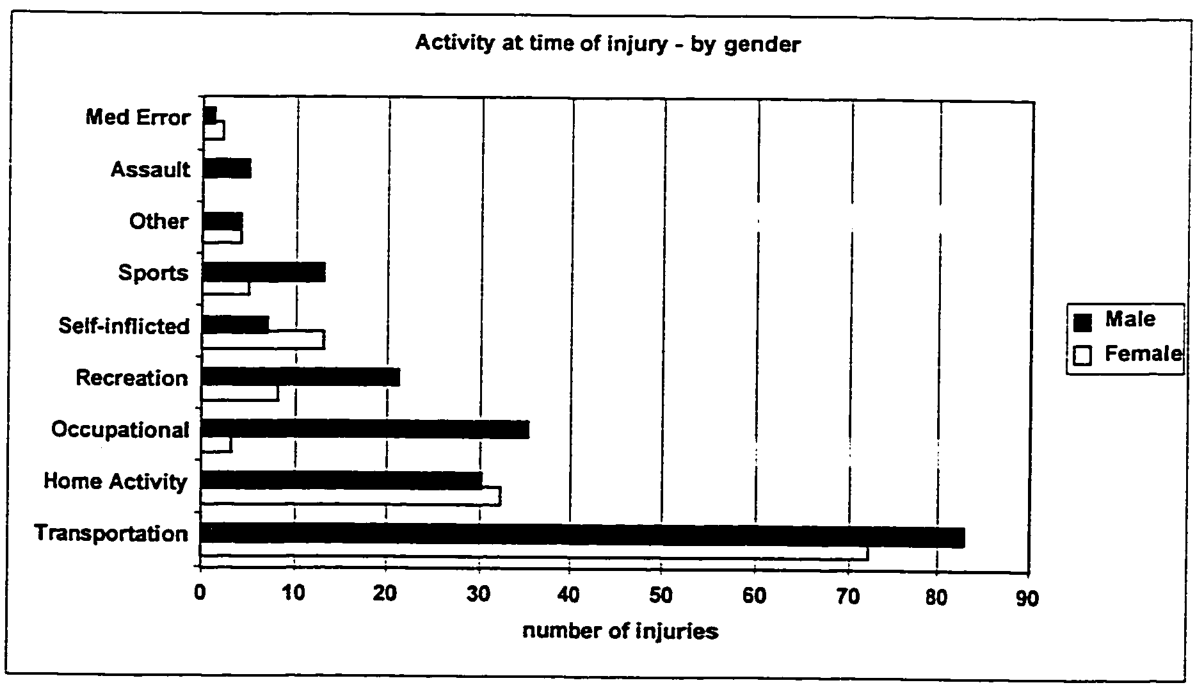


Figure 3.7 – Number of EMS responses to injury situations – by month

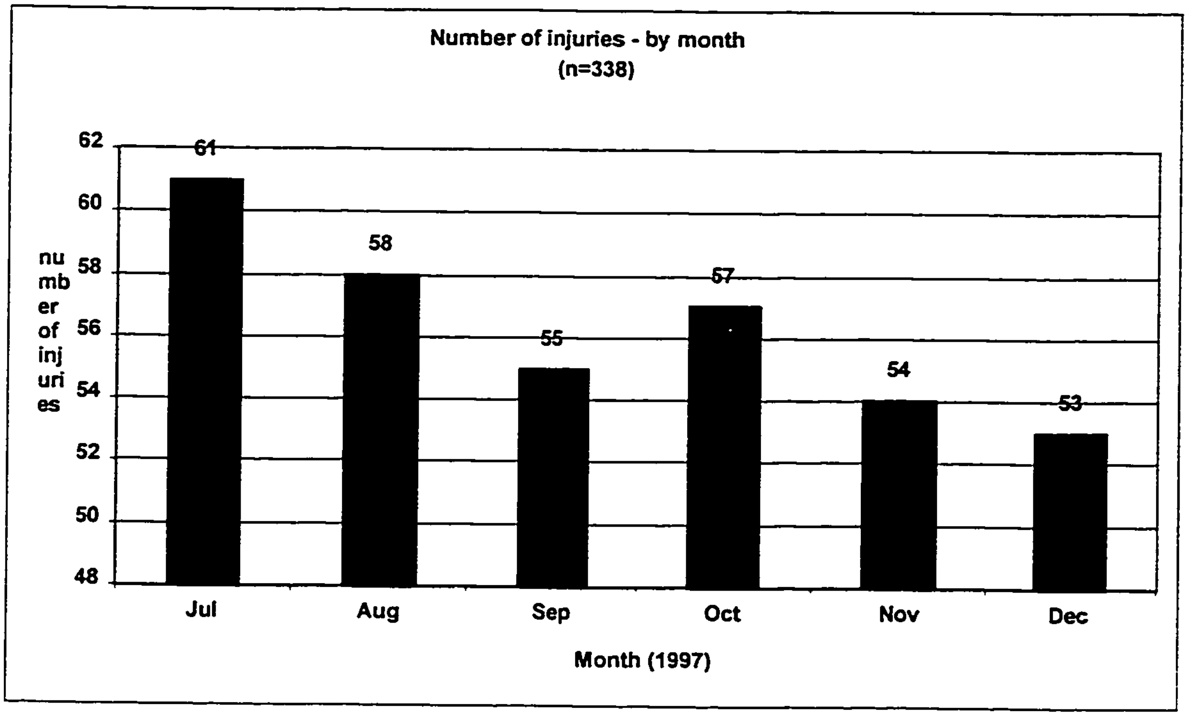


Figure 3.8 – Number of EMS responses to injury situations – by day of week

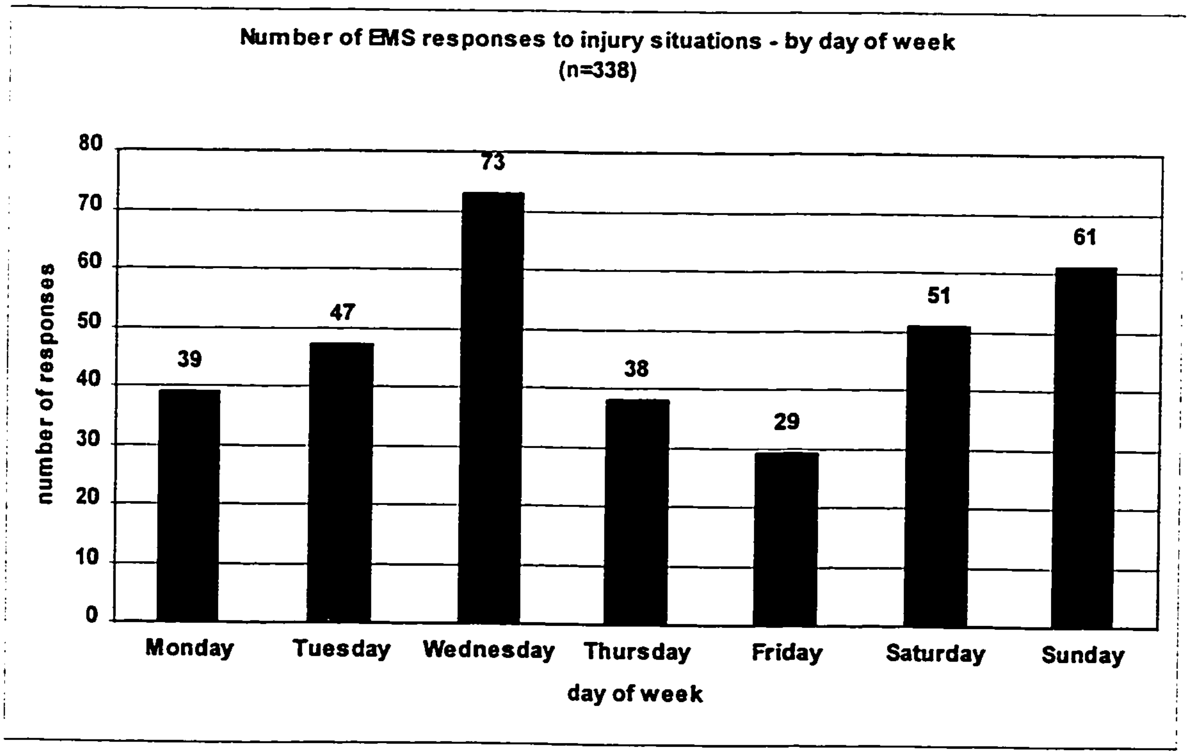


Figure 3.9 – Time of dispatch

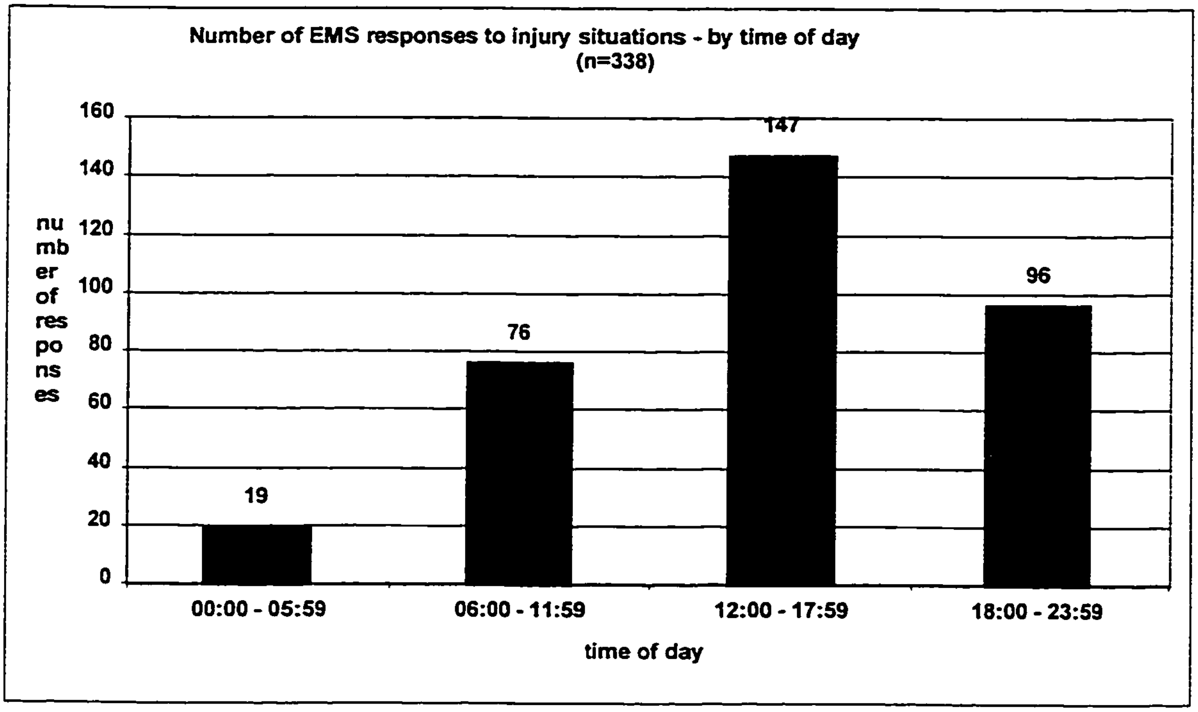
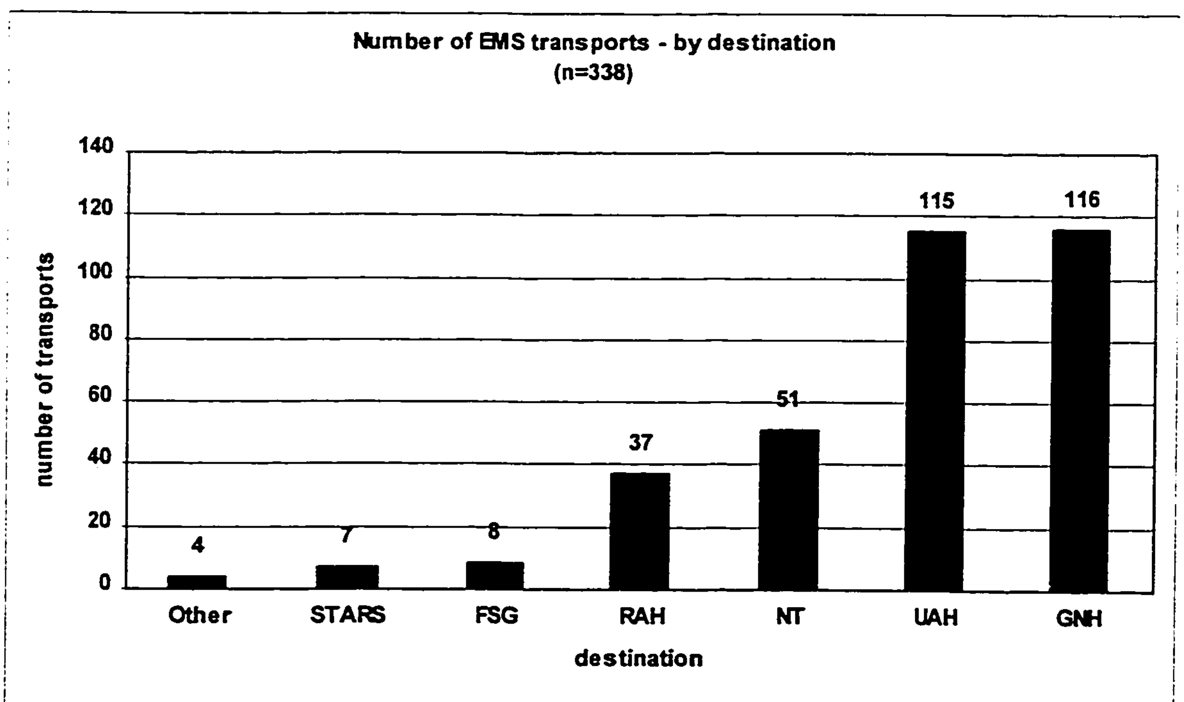


Figure 3.10 – Number of EMS transports – by destination



STARS	Shock Trauma Air Rescue Society (helicopter)	FSG	Fort Saskatchewan General
RAH	Royal Alexandra Hospital	NT	No Transport
UAH	University of Alberta Hospitals	GNH	Grey Nuns Hospital

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Chapter 4

Design and Implementation of an Emergency Medical Services Injury Data Collection and Patient Management Software Program

4.1 Introduction

There is little work published in the literature regarding the design, implementation, and evaluation of computer software designed for prehospital data collection and patient encounter management. There are several examples of such software in the commercial realm. There are no studies in the medical literature, however, that outline the data sets utilized by the prehospital software packages or how such software contributes to surveillance of injury and disease. This paper initiates discussion regarding prehospital-based injury surveillance and prehospital data collection systems by outlining the design, development, and implementation of a prehospital computer software program created to support injury surveillance efforts. The system was developed in the Department of Public Health Sciences, Faculty of Medicine and Oral Health Sciences, University of Alberta. The pilot site for the project is Strathcona County, Alberta, Canada, a mixed urban/rural community immediately east of Edmonton, the nearest urban centre.

The need for a computerized injury surveillance system in the province of Alberta, Canada, is made evident by the lack of accurate, timely, and readily available injury surveillance data for injury research. The Dynamic Injury Data Program is an effort to develop, implement, promote, and utilize a computerized injury surveillance system that will encompass prehospital, acute care, and rehabilitation data sources to better understand how, where, why, and to whom injuries are occurring, and to determine best treatment practices for injury. The prehospital system outlined in this paper is the first phase in the implementation of a large-scale computerized injury surveillance system. The development of the prehospital phase is a proof of concept intended to serve as a test-bed for development of the data collection and patient management software and other related technologies. Knowledge and experience gained from this phase will directly contribute to the definition of injury data sets and the design of software for other modules of the surveillance system. Furthermore, the experience and knowledge gained from development of this injury surveillance system can be applied to the development of other epidemiologic surveillance systems.

Epidemiology and health informatics are related in that both fields are concerned with the systematic processing and analysis of data relating to medical science. Epidemiology utilizes data to study the trends, distribution, and determinants of diseases and injury in a population (Hennekens et al, 1987). The goals of health informatics are to provide solutions to data and information processing problems, and to study the principles of data and information processing in medicine and health care (Hasman et al, 1996). Put another way, health informatics "determines and analyzes the structure of medical information and knowledge, whereas medical science is constrained by that structure" (Shortliffe & Perreault, 1990). Methods and tools borrowed from health informatics can supply a framework with which epidemiologists can better design information systems to carry out investigations. The validity and reliability of an epidemiological study is determined by the strength of the study's design and the quality of its data. The quality of a data processing system, therefore, can directly influence the quality of a study in which it is being used. Thus, it is important that the design of an information system that will support an epidemiological study be as well thought out as the study itself.

Epidemiologic (or public health) surveillance is "the systematic collection, analysis, interpretation, and sharing of health data for the design, implementation, and evaluation of public health programs" (Langmuir, 1969). Visions of future epidemiological surveillance invariably include advanced computer and communications systems linked to a multitude of data sources including individual households and medical facilities (Dean et al, 1994). The road to this particular future is wrought with obstacles, however. Such obstacles include the lack of a truly ubiquitous and uniform electronic patient record – records systems store many different variables in many different formats largely incompatible with each other (Dean et al, 1994). Extracting epidemiologically useful data from systems designed with no such capability for analysis in mind has proven to be difficult (Evans et al, 1997). The many recent advances in computer technology, information management, and global communications are making possible, and indeed necessary, standardized medical terminology, database designs, and record formats that can be shared among researchers worldwide (DiPisa et al, 1997).

Most epidemiological studies and public health surveillance systems still utilize paper-based records for primary data collection. The information contained on the paper records is usually entered into a computer only for statistical analysis; in doing so, however, the probability of errors being introduced into the system during transcription increases. Estimates suggest that during large drug trials, 20-50% of all handwritten case report forms are unusable due to missing data points and illegibility, thus requiring studies to recruit more patients than necessary in compensation for poor data quality (Beinlich et al, 1993). Clearly, poor quality paper records can increase costs, time, and work necessary to undertake research studies.

The weaknesses of paper-records (for epidemiologic studies and for patient care records) include extensive filing requirements, poorly organized forms, legibility of data, and redundancy (i.e., filling out a form by hand, then transcribing it into the computer). For epidemiologic purposes, perhaps the biggest drawback to paper-based information is that it is not coded or structured. The advantages of computer-based records include access speed, accessibility of data, accuracy of data (facilitated by automatically checking entries and offering choices in pick-lists), and ability to easily aggregate data for studies, provided that the resulting data are in a coded format. Disadvantages of computer records include high initial cost, need for training, security issues, computer failures, and compatibility of data across different platforms. Designed and implemented properly, methods and tools from the information systems field can allow epidemiologists to capitalize on the benefits of computerized systems while minimizing the disadvantages.

4.2 Methodology

4.2.1 Purpose

In order to support the prevention of injuries, accurate, timely, and readily available injury surveillance data are necessary; computerized systems are best situated to provide such data. Being part of established trauma systems, EMS systems can offer important data to injury surveillance systems. However, EMS-based injury information is seldom scrutinized for epidemiological research. The vast majority of EMS documentation is on paper-based forms rather than on computer. In cases when EMS data are entered into a system, the data are manually typed into a computer. Because computerized trauma registries and injury surveillance systems can greatly enhance injury research, development and implementation of a computerized prehospital EMS-based injury surveillance system (EMS-ISS) was undertaken to improve the quality and timeliness of data available to injury researchers. The purpose of this paper is to address the need for a computerized EMS-based data system to supplement injury surveillance research. This paper discusses the design, development, and implementation of a computerized system that will both automate the collection and analysis of injury surveillance data and serve as a patient management tool for EMS personnel.

When developing systems, the problem definition should clearly state the "big picture" problem without any reference to an intended solution, and stated in the users' words, not technical jargon. (McConnell, 1993). This is to prevent solutions from being developed without a clear idea of what the problem is and to prevent the wrong problem, or a non-problem, from being solved. The real-world and practical problem prompting the development of computerized injury surveillance systems is the lack of accurate, timely, readily available, and easily accessible injury information. In other words, **"how do injury researchers improve the quality and timeliness of the data on which they base recommendations for prevention countermeasures."**

There were several important steps, outlined in Table 4.1, used in the creation of the prehospital data collection and patient management software. Focus groups were established to ensure that the proper technical, scientific, and content-specific expertise was available. The *injury surveillance data requirements* were established so that, above all, the data gathered by the software would be sufficient for injury surveillance purposes. The *operational requirements* of the software were defined so that developers were able to design a system that met the requirements of EMTs and paramedics for use in the field. Based on the operational requirements for the software and the data collection needs of EMS services, the *clinical data model* was established to guide development of the dataset to be collected with the software and to provide some structure to the information normally recorded by EMS crews. Development of the clinical data model entailed examining existing EMS documentation and developing a *patient encounter model* able to provide a framework for and to break into logical components the assessment and treatment aspects of the EMS-patient encounter. Development and testing of the software was the final stage of the project, and was undertaken once the data and operational requirements were established and finalized. The data and operational requirements served as the framework around which the software was built. Although the design process was iterative, in that EMS personnel suggested modifications and improvements to the interface and usability of the software during the design stage, the data and operational requirements remained frozen during the development process.

Table 4.1 EMS software development steps

1.	Establish focus groups
2.	Define injury surveillance data requirements
3.	Define operational requirements of the software
4.	Develop the clinical data model
5.	Develop the patient encounter model

4.2.2 Focus Groups

The development of the EMS-based injury data system relied on the expertise of two focus groups: EMS personnel and injury control consultants. Representing EMS interests, a panel of EMTs and paramedics from Strathcona County Emergency Services (S.C.E.S.), the EMS provider in Strathcona County, was established. During the design phase of the project, the EMS focus group provided invaluable EMS content and domain expertise, assisted in the development of the pre-hospital data set for this system, and provided input for the operational requirements of the software. During the development phase, the EMS focus group supplied feedback and advice regarding the user interface, usability, and utility of the software. During the testing phase, members of the EMS focus group entered test data into the system to ensure the software performed as it was designed to.

The injury control consultants for this project are professionals who will utilize the surveillance data for injury control and research by coordinating pre-hospital, acute care, and rehabilitation services, for guiding injury prevention efforts, and for evaluating interventions and the surveillance system itself. The injury control group members consist of injury epidemiologists, community injury stakeholders (including EMS administration), and health care professionals who deal with injury. During the design phase, the injury control consultant group assisted with identifying the injury surveillance requirements and defining the injury surveillance data set. During the testing phase, in which the preliminary data was analyzed, the group participated in designing appropriate database queries and analyzing and interpreting the data to assess its surveillance value.

4.2.3 Injury Surveillance Data Requirements

There is no ubiquitous injury surveillance data set. There is, however, agreement among injury researchers regarding the most important data set elements. To develop the injury surveillance data set for this project, system designers consulted the injury control consultant group to determine their data requirements for effective research and other utilization of the data. The injury control consultants identified the need for a data set that is comprehensive with respect to person, place, time of injury, nature of injury, cause of injury, and other factors associated with the outcome of an injury event. It was also identified that the core data set should be common across injury surveillance system components under development (i.e., EMS, acute care, and rehabilitation). These needs were balanced with suggested injury surveillance data sets already published (i.e., Graitcer, 1991; Teutsch 1994). Table 4.2 is the injury surveillance data set around which the pre-hospital injury surveillance data system is based. This core data set serves as the starting point for integrating information from different injury data sources into a comprehensive, flexible, and representative computerized injury surveillance system capable of delivering accurate, timely, and readily available data. This core data set specification is the foundation on which this, and other DIDP injury surveillance system development, is based.

Table 4.2 Injury surveillance data requirements

Person	Age, gender, weight
Location	Place where the injury occurred
Time	Date and time when the injury occurred.
Nature of injury	Part(s) of the body injured (i.e., fractured left arm).
Cause of injury	Description of how and why the injury occurred. (E-code)
Other factors	Any other factors impacting the injury (i.e., seat belt / motorcycle helmet use)

4.2.4 Operational Requirements

The requirements analysis phase of development describes what the software system is supposed to do for the user (Manas, 1997; McConnel, 1993). Table 4.3 outlines the five major operational requirements of the software program. The first requirement of the system is that it be designed for use in the field on portable computers (either laptops or hand-held pen-based computers). The second requirement of the software is that it function as not only an injury data collection tool but also as a prehospital care patient management tool. The third requirement is that data be uniform and standardized, and coded to permit easy and efficient data entry and subsequent data analysis. The fourth requirement of the software is that it support continuous quality improvement (CQI) initiatives. The fifth requirement of the software is that it support timely injury surveillance efforts by permitting electronic data upload to a central computer.

Table 4.3 Software requirements summary

1. Software to be used in the field by EMS personnel
2. Facilitate data entry for all EMS calls, not just injury calls
3. Promote standardized documentation practices
4. Support continuous quality improvement (CQI) efforts
5. Support injury surveillance efforts

The EMS focus group created a "wish list" of software features intended to improve their data entry efficiency. The EMS group clearly stated their requirement for a cleanly designed user interface. The graphical user interface (GUI) should facilitate efficient data entry through the liberal use of check-boxes, pick-lists, and other automated data entry tools optimized for stylus-based entry. Although there is a lot of information to capture using the system, the EMS focus group decided it was better to have many different screens in the software rather than fewer screens with more information contained on them. This is to ensure that all "targets" on the computer screen (i.e., buttons and lists) are large and easy to click with the cursor and that the display screens are cleanly-designed. The EMS focus group also identified the need for the software to generate and print a standard PCR from to be left at the hospital after the ambulance call. A benefit to hospitals of a printed-out PCR is that it eliminates problems created through illegible handwriting and otherwise poorly documented forms.

The first requirement of the software is that it be designed for use in the field by EMTs and paramedics. Direct computer entry of data by EMS personnel will eliminate the redundancy in data entry that currently occurs. In the County, when EMS crews return from an ambulance call, the patient care report (PCR) completed in the field is submitted to administrative personnel who enter certain data elements (i.e., demographic information, A.C.E. codes, treatment codes) into a computer for administrative analysis. Information entered into a computer by EMS personnel in the field will store all data regarding the call in electronic format, and will eliminate errors being introduced into the data due to the transcription process. Other advantages of direct data entry will include the ability to upload patient information to hospital information systems (if available and compatible) to eliminate the need for re-taking of information and event history by hospital staff. For a computer program to be easy and efficient for EMS personnel to utilize in the field, however, the software must be designed with the needs of the EMS personnel at the forefront. A simple forms-based data entry system utilizing an off-the-shelf database program is inadequate; a customized software solution is the answer. However, a customized computer program requires a tremendous amount of development work with extensive consultation with the end-users. Another important consideration for a system to be used in the field is the hardware platform on which the software operates. The desire for the system to be portable limits the choice of hardware to either laptop-type computers or pen-based hand-held computers.

The primary reason for developing a computerized prehospital data collection program is to support the evolving injury surveillance system under development at by the Dynamic Injury Data Program team. In order for a computer system to achieve regular use by EMS crews, however, it would need to function as more than just an injury data collection system. In Strathcona County, injury-related ambulance calls comprise only 20-30% of all EMS calls. An exclusively injury data collection program would therefore be useless for up to 80% of the ambulance calls, which would still need to be completed on paper PCRs. In order to avoid a dual documentation system (computer and paper), the second requirement of the system is that it accommodate the documentation requirements of all EMS calls whether injury related or not.

Current EMS documentation practices rely on the personal style and attention to detail of the EMT or paramedic filling out the forms. Many EMS personnel complete very detailed documentation of patient care whereas others record the basic assessments and treatments but do not include as much auxiliary information. EMS documentation often contains a mixture of colloquial and medical terminology when describing anatomy and assessments. The third requirement of the software, therefore, is that it facilitate standardized recording of data using a uniform, fixed vocabulary. This will in turn facilitate data analysis and coding of injuries using standard E-codes and other coding schemes.

An important aspect of an EMT's or a paramedic's career is continuous training to ensure that he or she is proficient at their job and are aware of new and better treatment practices. To support EMS training, or continuous quality improvement (CQI), it is important that EMS training officers are aware of EMS crew's proficiency levels. The fourth requirement of the software is that it support CQI efforts by documenting not only what procedures, such as intubations, were performed, but which crew member performed the procedure.

The primary reason for developing computerized injury surveillance data collection software is to promote and support the collection of accurate, timely, and readily available injury data. In order for the software to support injury surveillance efforts, it is necessary to permit rapid turnaround of the data so that injury control personnel can analyze the data to determine patterns in the occurrence of injury, to identify which people, places, and behaviors are at risk of injury, and to develop intervention strategies. To facilitate this, when the EMS crews arrive back at the station, they will upload data into a central computer for analysis.

4.2.5 Clinical Data Model

The clinical database is the environmental-specific data set that is required for the software to be operationally effective. The first step in developing the clinical data model was to examine existing EMS documentation forms and requirements. In the province of Alberta, it is currently legislated that all EMS units utilize a standardized patient care report (PCR). The patient care report is three pages in total; the front side of the second two pages is a carbon copy of the first page. Table 4.4 lists the major fields on the patient care report form. The back side of each page contains different information including lists containing treatment procedures, drugs/solutions, destination codes, and a list of abbreviations. The third page of the PCR is intended for Alberta Health, and besides the "normal" PCR fields, contains places to write codes for which treatments were given and which medications were administered (these codes are on the back of the first PCR page). This page also contains check boxes for safety devices used (lap belt only, shoulder and lap belt, air bags deployed, motor/bicycle helmet, child safety seat, and other). The back of the third page is where EMS crews record the "ACE" codes, for Activity, Cause, and Effect. The ACE codes are an attempt to codify aspects of the call, including type of injury, mechanism of trauma, and setting at time of injury. While potentially an important source of injury information, ACE codes are rarely entered consistently.

Table 4.4 Patient care report form fields

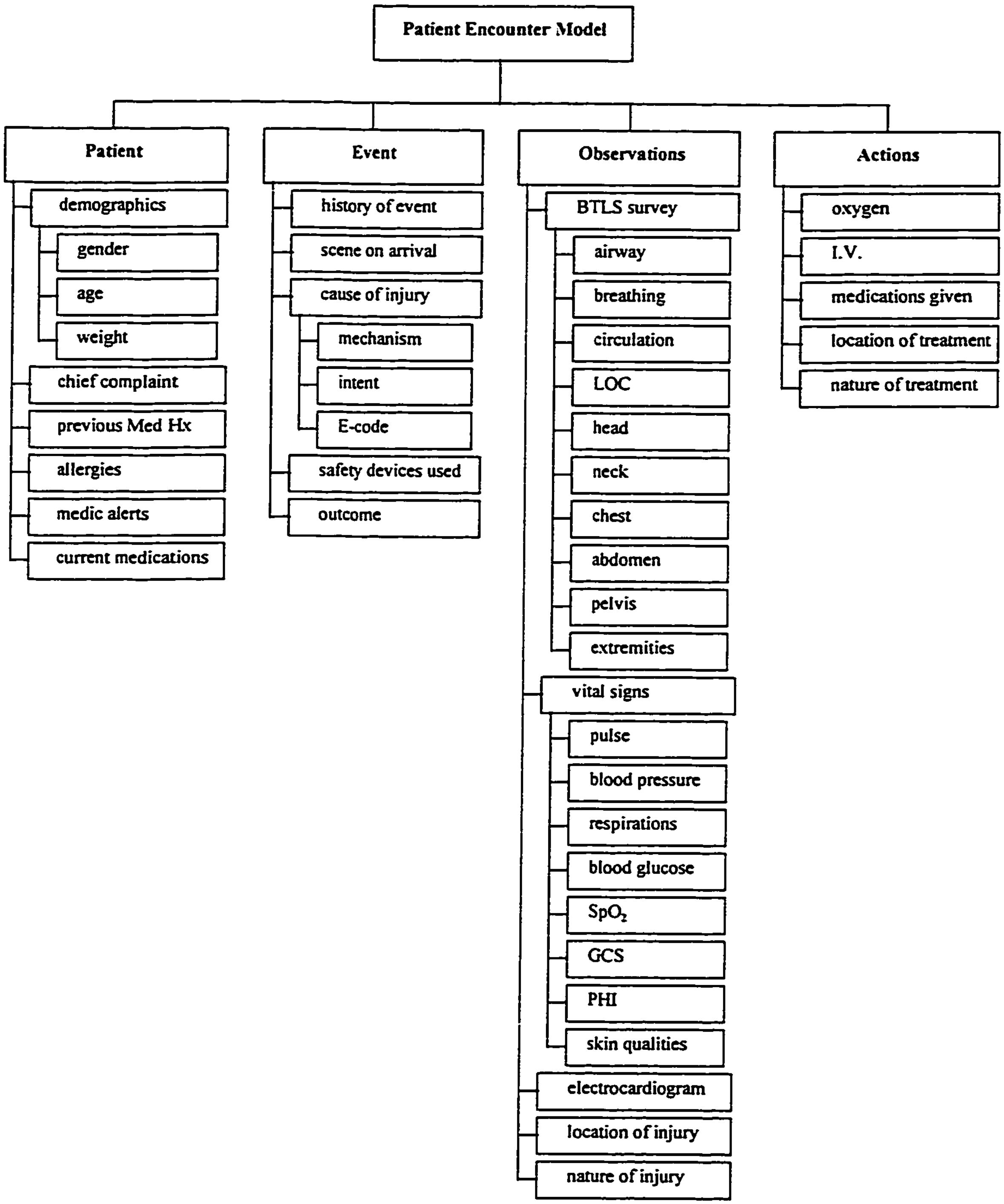
Administration	Date of service, address responded to, response level (ALS, BLS, EMR), run number, invoice number, destination (name and code), time call received, time of EMS response, time arrived on scene, time left scene, time arrived at hospital, hospital file number, total distance travelled, name of police involved (if any), transfer status, air ambulance dispatch number, attendants' names and registration numbers
Patient Demographics	gender, name, birthdate and age, weight, mailing address, city/province, postal code, telephone number, next of kin (including relationship, address/phone), personal health number, Blue Cross number, physician, WCB claim (yes/no), employer, business telephone, occupation, treaty number, band name, DVA/SIN/DPH number, social worker name, social services number
Medical History	chief complaint, previous medical history, allergies, medic alerts, current medications
Vital Signs	time, pulse, blood pressure, respiration rate, Glasgow Coma Scale (GCS), pre-hospital index (PHI), skin, SpO_2 (%), Blood Gas Level (mmol/L)

The predefined fields of the PCR, which are for administrative and billing purposes, contain information useful for demographic analysis including the patient's age, gender, weight, and the location to which the ambulance responded (which serves as a proxy for geographic location of injury). However, a major portion of the PCR is reserved for the EMT's or paramedic's narrative in which the scene, event, findings, and treatments are described in detail. The bulk of the clinical data, and information relevant to the assessment and treatment of injuries, is contained within the free-form narrative of the patient care report. Because the narrative is usually quite detailed, it is also the part of the paperwork that consumes the most time. Once the patient is handed over to hospital staff, completing a PCR can take upwards of half an hour or more, depending on the complexity of the call. Like most medical documentation, the EMS narrative contains a wealth of information. The information contained within the narrative, however, has no research value unless its key points can be extracted and analyzed.

One method of codifying narrative information is for users to type the narrative into the computer as they would write it on the PCR (in free-text format). Following this, an algorithm could extract the relevant information from the narrative for coding purposes. This procedure is somewhat common, and there has been much research in this area of extracting medical information from free-form text (El-Gamal et al, 1995; Tange et al, 1997). An extraction procedure would not be best suited in the EMS environment, however, because it would still require crews to type a long narrative at the end of the EMS call. The EMS focus group recommended that the software be constructed to permit entry of individual patient encounter elements (such as assessments, treatments, and medications delivered) in a codified and structured manner. The EMS group also recommended that a patient care narrative (or summary) be automatically drafted at the end of the call based on the data entered into the system. This entails decomposing the patient encounter into its component parts, designing the software so that the component parts can be entered in a non-linear fashion, and designing an algorithm to compose a text narrative at the end of the call based on the data entered during the call. The result would save crews from having to compose a long narrative, and would create a structured, coherent, and concise record of patient care. Furthermore, the breaking down and codifying of the narrative information would greatly improve the ease of data analysis and interpretation. As well, errors based on extraction of information from free-form text would be eliminated.

To facilitate the development of the clinical data model, a model to describe a "typical" patient encounter was developed. This Patient Encounter Model (PEM) specifies discrete components of the patient encounter which can be individually analyzed, codified, and utilized for efficient data entry in the software. During development of the PEM, PCR narratives, EMS personnel training manuals, and SCES standard operating procedures (SOPs) were examined to synthesize a patient encounter template. A PCR narrative typically covers four general areas: patient information, event description, findings upon examination, and treatments administered. Although these sections may appear in a different order on the PCR depending on the writing style of the paramedic or EMT, the information within each section is relatively consistent. Roughly emulating PCR narrative format, the PEM was designed with four primary categories - patient, event, observations, and actions.

Figure 4.1 – Patient encounter model



The **patient** section of the PEM contains basic demographic variables, a description of the patient's chief complaint, and a listing of medically important variables (previous medical history, allergies, medic alerts, and patient's current medications). The patient section is straightforward because it contains information that is objective and easily codified, and therefore is easily entered utilizing pick-lists and check boxes. As is problematic with most medical documentation, information such as current medications, previous medical history, and medic alerts is subject to a patient's recall bias or unwillingness to disclose all pertinent information to the EMS crew.

The **event** section of the PEM contains information pertinent to how and why an injury event occurred. This section allows for two short descriptions: one outlining the history of the event (i.e., what events led up to the injury), and one outlining the scene on arrival (a description of the state of the patient and surrounding environment when first encountered by EMS personnel). The event history is potentially very valuable to injury researchers, as it contains information about the mechanism and intent of the injury. The event section also codifies the cause of injury in the form of mechanism, intent and ICD-9-CM E-code (external cause of injury). The utilization of any safety devices is recorded in this section, as is the outcome of the patient (when known).

The **observations** category is a detailed section outlining diagnoses and assessments made by the paramedic or EMT encompassing the signs, symptoms, or status of the patient during the encounter of which the EMS crew wants to take note. The Basic Trauma Life Support (BTLS) patient assessment survey is a qualitative assessment guide adhered-to by EMS crews while assessing a patient. The BTLS survey consists of a systematic overview of the patient's airway, breathing, circulation, and level of consciousness, and guides examination the patient's head, neck, chest, abdomen, pelvis, and extremities. Because EMS crews are trained to BTLS specifications and they are intimately familiar with the BTLS survey, the BTLS survey was adopted as a primary assessment framework for the software.

Vital signs are a quantitative measure of aspects of a patient's physiology including pulse, blood pressure, respiration rate, blood glucose level, skin (color, temperature, moisture, turgor), and partial pressure of oxygen (SPO_2) in the blood. The Glasgow Coma Scale (GCS) is a measure of the patient's neurological functioning and assesses the patient's spontaneity of eye-opening, verbal response, and motor response. The score ranges from 3, meaning no neurological response, to 15, which indicates unhindered neurological response. The pre-hospital index (PHI) is a triage tool with which EMS crews can assign a score and judge quickly whether transport to a trauma centre is warranted. The PHI is assigned by assessing the patient's blood pressure, pulse, respiration, consciousness, and determining the presence of any penetrating head, chest, or abdominal wounds.

The location of injury is the body region or anatomical location of the injury (i.e., "left forearm"). Pick lists are an excellent way to standardize data collection by permitting the user to enter only data that is chosen from a list of possible options. Pick lists become very inefficient with respect to the time it takes to find an item if the lists are exceedingly long (Poon et al, 1996). To standardize nomenclature with respect to anatomical locations using a pick list would require a list with dozens, if not hundreds, of entries. A list of such length would render data entry slow and painstaking. A mechanism was needed to reduce the number of choices on a list to a manageable number. To address this, developers of MODES-EMS adopted the BTLS assessment body regions to form the basis for a hierarchical body region selection structure in which users can navigate, or "drill down", from general body regions to very specific anatomical structures or regions. The body region selection structure consists of three levels. The first level body regions are: head/neck (not including c-spine), chest, abdomen, pelvis, extremities (arm, leg), and back (including spinal column). Each of the first level regions, or "parents", links to one or more second level regions ("children") that are associated with it. For example, second level regions for "arm" are "shoulder", "upper arm", "elbow", "forearm", and "hand". When anatomical specificity requires, certain second level regions are linked to third level regions. For example, third level regions for "hand" are "thumb", "first digit", "second digit", "third digit", "fourth digit", "palm", and "wrist". Not all second level regions have associated third level regions. Using this method of navigating through levels of anatomic specificity decreases the amount of scrolling through choices and ensures standardized coding of information (by ensuring that structures are consistently and uniformly named).

The nature of injury is the type of injury that occurred (i.e., "burn"). An assessment of the nature of an injury is always linked to the anatomical location of an injury. The nature of injury includes descriptions of the amount of bleeding and swelling, the quality of pulses distal from the injury, and quality of motor control, sensation, and range of motion of any injured extremities. There are many different assessment that EMS personnel can make regarding an injury in particular or about the general status of a patient. In order to streamline the data entry process for assessments, a hierarchical assessment selection system similar in concept to the body region selection structure was developed. In the system, the three main classes of assessment are "superficial", "skeletal", and "internal". The superficial category includes assessments such as laceration, abrasion, and contusion; in other words, assessments that are plainly visible from the surface. The skeletal category includes assessments such as fracture and amputation. The internal category consists of internal injuries including pneumothorax and flail chest. An advantage of linking the body region with the assessments section is that only assessments applicable to certain body regions (i.e., pneumothorax is applicable only to the chest) need be presented. This reduces the number of items from which users must choose, and reduces the chance of recording nonsensical assessments (for example "evisceration of the right thumb").

The **actions** category consists of treatments or medications administered to the patient during the encounter. Actions encompass the administration of oxygen to the patient, the infusion of fluids via an intravenous (IV) line, and the delivery of medications. Table 4.5 outlines the fields captured in each action category. The actions category also include the description of specific treatments such as spinal precautions, endotracheal intubation, and splinting, and specifies the anatomical location at which the treatment was applied (if applicable).

Table 4.5 – Action category data fields

Action	Field Name	Choices (or range)
Oxygen	Flow rate	
	Administration route	Nasal cannula; non-rebreathing bag; bag-valve mask; pediatric mask
I.V.	Solution	normal saline; ringer's lactate
	Infusion rate	
	Amount infused	
	TKVO (to keep vein open)	yes/no (check box)
	Drop rate	10gtt; 60gtt
	Needle gauge	10-20
	Needle location	
Medications	Medication name	<chosen from medications list>
	Medication dose	
	Dose unit	g; mg; mcg; mL; cc
	Administration route	intravenous, intramuscular, oral, topical

Injury assessment information and treatment information are linked via the body part specified, when applicable. For example, a bodypart might be identified as "left palm", nature of injury might be "laceration" and treatment might be "bandaging". Assessments and treatments are linked in this fashion to facilitate understanding how the two are related, to contribute to CQI efforts, and to better learn what treatments are most effective for what injuries. There is a "general" category to be used when there is no specific bodypart to which a treatment applies (i.e., extrication). All assessments, treatments, and bodyparts are contained in pick-lists. This serves to, in effect, codify and standardize the input so that later extraction and analysis of data is simplified.

4.2.6 Software Development

Once the data requirements and specifications of the software were completed, they remained frozen during the development phase of the software. Although the design of the software was iterative, the requirements and specifications served as a blueprint for development, and it was important to ensure that they did not change during the development process. Design was iterative in that early prototypes of the software were tested with the EMS focus group to ensure that the interface and software in general performed to specifications. This permitted development to account for the needs of the EMS personnel who will be using the system.

The next step was to determine the most appropriate platform for which to design the system. There are many competing portable computer platforms available, including the Apple Newton™, PalmPilot™, several Windows™-based hand-held computers (i.e., Fujitsu Stylistic™ 1000) and a myriad of Windows-based laptop computers. We chose the Fujitsu Stylistic 1000, a Windows 95 compatible hand-held pen-based computer as the hardware platform on which to test the software in the field. After careful considerations, the Windows 95 platform was chosen for several reasons. First, most computer users are familiar with the Windows interface and are familiar with the general operation of Windows-based software. Second, even though the software is designed for optimal use on portable computers, it will still operate on standard Windows-based personal computers. This is an ideal situation for training purposes, so that the portable hardware is always available for operational use. Third, the Windows-based portable hardware is larger and more rugged. For our prototype development and testing, the Fujitsu Stylistic 1000 pen-based hand-held computer was selected because it offered the best combination of computer performance, screen size, weight, cost, and durability. See Appendix A for Fujitsu Stylistic 1000 hardware specifications.

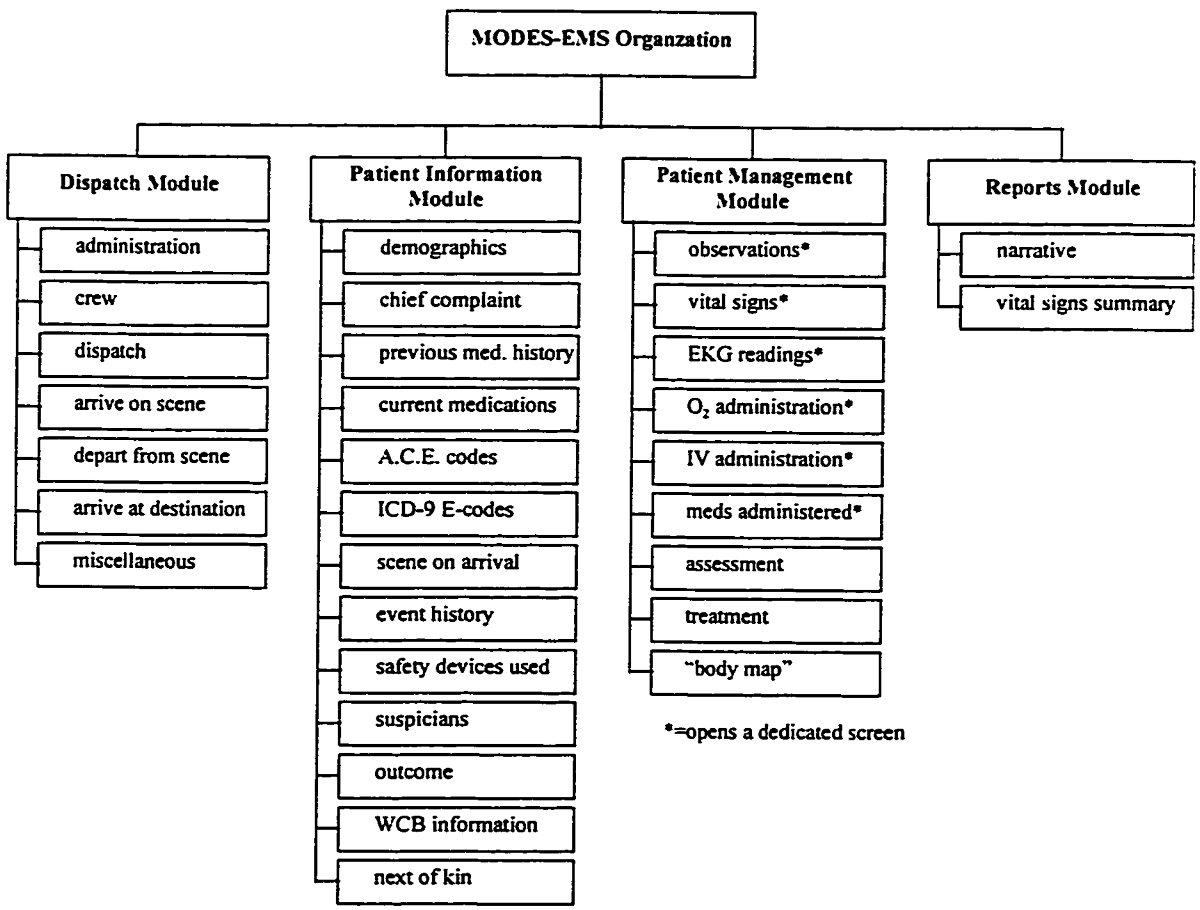
MODES-EMS was developed as a prototype pre-hospital data collection and patient management tool in Microsoft Visual Basic™ Professional Edition version 4.0 (and re-compiled on version 5.0). Visual Basic ™ (VB) is a rapid application development (RAD) tool that permits relatively quick design and testing of software and is ideal for prototyping purposes. A RAD environment was important to support the iterative nature of the development of the software. Another feature of importance of VB is that the database "back-end" is the Microsoft Access ™ "JET" engine. Because Access is a very popular database program, and is the database on which our injury surveillance database is to be initially prototyped, it was important to have that instant compatibility for ease of data transfer and eventual analysis. Disadvantages of software developed in the Visual Basic™ environment are that it does not create fully compiled code (which results in slower execution of the program) and that it relies on many support files.

4.2.7 Software Organization

MODES-EMS is not just a computerized version of the standard patient care report. It will print out a form identical to a PCR, but the manner and mechanisms of data entry are optimized for use in the field and are organized around the way EMS personnel are trained to assess a patient; furthermore, the system is flexible enough to account for unforeseen circumstances. To ensure the integrity of the data, the software checks the validity of data elements such as dates, times, and numbers to ensure that they are in the proper format. To further ensure data integrity, pop-up dialog boxes can be used to enter certain data types (dates and times, for example) to ensure no nonsense entries are made. The software supports handwriting recognition so that data fields can be printed directly onto the screen in the appropriate boxes. To supplement the handwriting recognition, a pop-up keyboard is available for entering field data.

MODES-EMS is organized into four functional modules: *Dispatch, Patient Information, Encounter Management,* and *Reports.* Access to the different modules is controlled through an overhead button bar, and control of the software's options, preferences, and features is available through the main menu. The MODES-EMS modules are functionally and logically divided so that information and tasks that are related to each other are placed within the same module. Within each module are contained sub-modules which further group similar data or software functions. Figure 4.2 illustrates the MODES-EMS software organization.

Figure 4.2 – MODES-EMS software organization



The Dispatch module of the software is essentially an administration module and is the portion of the computer program in which EMS crews enter information regarding the ambulance call. From the Dispatch module, users can enter and access call administration data (i.e., run number, invoice number), crew member names and registration numbers. Event times (i.e., call received, dispatch, arrive on scene, depart from scene, and arrive at destination) and related pertinent information (i.e., response level, address or location of scene, name of hospital) are entered on this screen. Miscellaneous data, including the name of any police on scene, time back in service, and total distance traveled are entered into this module. Figure 4.3 is a screen capture of the Dispatch module.

The Patient Information module (Figure 4.4) is the module in which information about the patient is entered. Patient demographic information, including the patient's name, address, phone number, date of birth, age, and gender are entered in this module (see Figure 4.5 for a screen shot of the patient information demographic section). The patient's chief complaint, previous pertinent medical history, allergies, and medic alert warnings are entered into this module utilizing pick lists. If necessary, the user can add custom items if not available from the standard list. Any medications a patient is currently taking is entered into this module – the system has a pharmacological database linked to the on-screen keyboard, from which EMS crews can pick appropriate medications. Figure 4.6 is a screen shot of the patient information history section. Figure 4.7, a screen shot of the patient information next of kin and WCB information section, shows the data fields for this section. The coding section includes an area in which ICD-9-CM E-codes (for external cause of injury) can be input as well as the province-wide standard "ACE" (activity, cause, and effect). Figure 4.8 is a screen shot of the patient information coding section.

Also enterable in the patient information module are the scene on arrival and event history descriptions, suspicions, and outcomes (see Figure 4.9 for a screen shot of the patient information Scene/outcome section).

The Patient Management Module (Figure 4.10) is the "business end" of the software, and is where EMS crews document their encounter with the patient. From this module, the user has access, via the click of a button, to all clinical aspects of that patient encounter, including assessments and treatments. To ensure that a limited, standardized vocabulary be utilized and that the data are stored in a structured and coded format, this module relies heavily on the use of a specialized user interface, content-specific dialog boxes, lists, and check boxes.

The three major sections of the Management Module are Event Management, Assessment, and Treatment. The Event Management section coordinates and tracks when observations, vital signs, and injuries were assessed, when EKG readings were taken, and when IVs, oxygen, medications, and treatments were administered. Each Event Management subsection has its own specialized "pop-up" dialog screen on which to record information. Figure 4.10 illustrates the Patient Management module with the Event Management section (including event tracking list and event buttons). As documentation of different aspects of the patient encounter are completed, the event tracking list provides a record of what has transpired. Figure 4.11 illustrates the fields associated with the Assessment section of the Patient Management module and Figure 4.12 illustrates the fields associated with the Treatment section of the Patient Management Module.

The left side of the Event Management module screen contains the Body Region Selection Control (BRSC). The BRSC consists of an image of a body (male or female, depending on the gender of the patient) in which is embedded a grid. When the user clicks on the image, the coordinates corresponding to that point are used to identify the first level region (i.e., head/neck, chest) and to select the most likely and appropriate second level regions. The image magnifies approximately 3 times to the region where the user clicked and the second level regions fill the body region list (immediately below the image). Once zoomed in, the user can specify the desired second level region by clicking on the image or by selecting the appropriate region from the body region list. If a second level region with associated third level regions is chosen, the third level regions populate the third level region list, to the right of the main body region list. From this point, the user can choose a third or second level region from the appropriate list box or choose the desired region by pointing on the magnified image of the body. Once a region is chosen, the computer places a description of the region in the box immediately above the body image. When describing the selection, the computer takes into account the side of the body, the hierarchical level of the selected region, and utilizes some custom-designed heuristics to create logical sounding descriptions. Table 4.6 illustrates some examples of computer-generated descriptions of body regions based on various levels of hierarchical region selection.

Table 4.6 – Example body region descriptions

L1 Region	L2 Region	L3 Region	Description
Extremities	Left hand	Thumb	"Left thumb"
Extremities	Left Hand	2nd Digit	"Second digit of left hand"
Extremities	Left Hand	N/A	"Left hand"

The Reports module of the software (Figure 4.15) is where the computer generates the patient care report for the EMS call. The computer generates a narrative based on the information entered by the user during the EMS call. The narrative composed by the computer consists of four sections. The first section, Patient Information, provides a summary of the patient's age, gender, weight, chief complaint, previous medical history, allergies, medic alerts, and current medications. The Event Description outlines the scene on arrival (O/A) by EMS crews, and the history of the event (HX). The Assessments section recaps the BTLS survey(s), and lists any other findings. The Treaments section outlines all treatments given, including IVs, oxygen, and medications. Below is a sample narrative generated by MODES-EMS.

```
PATIENT INFORMATION:
Patient is a 26 year old male weighing 90kg.
C/C: motor vehicle collision.
PMHx:  depression, ulcers.
ALLERGIES:  penicillin.
MEDIC ALERTS:  No medic alerts.
MEDS: Accutane

EVENT DECRIPTION:
O/A: Patient found lying supine on the ground in a ditch near the road.
Many bystanders are present.

Hx: Patient involved in T-bone collision. Patient was the restrained
driver of a mid-size car that was struck by a minivan. Vehicle was struck
at the front driver's side. No starring on windshield. No intrusion into
passenger compartment. No visible damage to interior of vehicle.

ASSESSMENTS:
O/E: AIRWAY: open. BREATHING: non-labored, regular, normal. CIRCULATION:
present, strong, regular. LOC: Patient is conscious, alert, oriented to
person, place, time, event. HEAD: unremarkable. Eyes PERL @ 4mm. NECK:
Jugular vein is normal. Trachea is midline. CHEST: Breath sounds present
and equal. ABDOMEN: unremarkable.
EXTREMITIES: Left forearm - laceration, bleeding, swelling. Distal pulse,
sensation, motor control normal.

TREATMENTS:
Patient extricated. Placed under full spinal immobilization.
O2: 5L/min via nasal cannula.
IV: normal saline, 10gtt, TKVO, left AC, 1/1 attempt. 800mL infused.
Left forearm: control bleeding, bandaging.
Fentanyl: 180mcg IV @ 1425. Pt reports good pain control.
```

The computer composes the narrative and places it in the narrative box on the Reports screen. The user can then make edit the narrative if necessary using the on-screen keyboard or an attached keyboard. The Reports module screen also includes a vitals signs summary of all vital signs taken during the EMS call.

4.3 Discussion

MODES-EMS was developed as a prototype prehospital data collection system with the intent that after a thorough evaluation of the system, it would be implemented on a large scale.

There are several limitations to the system as it currently exists that, once addressed, will even further the software's potential and utility for injury surveillance efforts.

One limitation is that the nature of the injury is not coded using ICD-9-CM nomenclature. This is a drawback because it limits direct comparison of prehospital data with hospital (i.e., emergency department), government, and other administrative databases that typically code using ICD-9-CM. There are several hurdles, however, to effectively coding prehospital information with ICD-9-CM. Primarily, EMS personnel are trained to make rapid assessments and to treat the most severe injuries first. EMS crews do not make "diagnoses" per se, but rather record observations, signs, and symptoms. To address this problem, a "crosswalk" could be developed to effectively translate the EMS assessments into ICD-9-CM coding by retrospectively applying a specially designed algorithm.

Another possibility to address the customized coding system developed for MODES-EMS is to adopt a standardized nomenclature systems such as SNOMED, which is the "Systematized Nomenclature of Human and Veterinary Medicine". SNOMED is a "comprehensive, multiaxial nomenclature classification work created for indexing of the entire medical record, including signs and symptoms, diagnoses, and procedures" (SNOMed, 1998). The goal of SNOMED is to integrate all medical information from a computerized medical record into a single data structure.

The software is not yet Health Level Seven (HL-7) compliant. HL-7 seeks to standardize electronic interchange of health-oriented data, including clinical, financial, and administrative systems, between independent health care computer systems. Making MODES-EMS HL-7 compliant will permit uploading of patient data from the hand-held computer to hospital computers (assuming they are HL-7 compliant). This will make possible a system in which a new electronic hospital chart is started and all pre-hospital information will instantly become part of the new file, and will eliminate the need to print out a paper-copy of the patient care report for hospital records.

The prototype software is not yet able to transmit information over a wireless system (i.e., wireless local area network, cellular digital packet data (CDPD) technology). Currently, data are transferable via a serial connection. Work will be done in the future, however, to incorporate wireless technology so that data can be uploaded to hospital administration computers, to computers back at EMS headquarters, and in fact transmitted from the ambulance in the field to the hospital to better assist readying trauma teams better prepare for the incoming injured patient.

Although great effort was made to codify information wherever possible within MODES-EMS, two significant areas suffer from a lack of any coding scheme at all. Within the Event module of the PEM, the scene on arrival and history of event are both free-form text fields. Although the cause of injury is stored in E-code format, there is much information contained within these two fields that could be of value for injury surveillance. The next version of the software could incorporate standard coding schemes for sports- and occupation- related injuries and. As well, a customized dialog box could be developed for illustrating important aspects of motor vehicle crashes include where in the vehicle the patient was sitting, where the patient's vehicle was struck, where any internal damage is within the car, and the presence of any exterior environmental factors.

Admittedly, further work is necessary to ensure that the security systems built into MODES-EMS are capable of protecting patient information when the system becomes fully operational. "The use of data processing and telecommunications in the health care area must be accompanied by appropriate security measures to ensure data confidentiality and integrity, protecting patients as well as professional accounts, and organizational assets" (Makris et al, 1997). For testing purposes, no data that could identify an individual (i.e., name, address) was entered into the system. However, before the system is fully operational, work will be completed to enhance password protection and to encrypt patient information (especially if information is going to be transmitted over a wireless system).

Remote data entry into computers has been found to reduce the volume of corrections and missing data, automatic reminders typically improve record completeness, and validity checking of data input reduces input errors. Studies suggest that although it initially can take some additional effort to properly enter data into computer systems when compared to paper documentation, the real time saved is realized during data analysis and interpretation due to structured and codified data (Beinlich et al, 1993). When entering the 338 test records (actual PCRs completed in the field), it took approximately 15 minutes per record to read and abstract the PCR and to enter injury-related information into the program.

Provided that the systems are designed properly with research in mind, computerized data collection will improve the quality of data available for epidemiological research. This prototype will form the basis for future versions of the EMS software and will be a template for the development of other injury surveillance modules' data collection software. The goal of accurate, timely, and readily available injury data will be greatly facilitated through the use of electronic data collection systems. This system was developed with extensive consultation with the users of the software (EMS personnel) and users of the data (injury control stakeholders in academia and in the community). Injuries cost the Province of Alberta billions of dollars annually whereas injury interventions are typically inexpensive and provide enormous payback. However, surveillance information is required to drive research into injury interventions and injury control. When this system is fully implemented and operational, and when injury stakeholders are able to access the data they need to better predict and prevent when, where, and to whom injuries are occurring, the true value of computerized injury surveillance systems will be realized.

Figure 4.3 – MODES-EMS dispatch screen

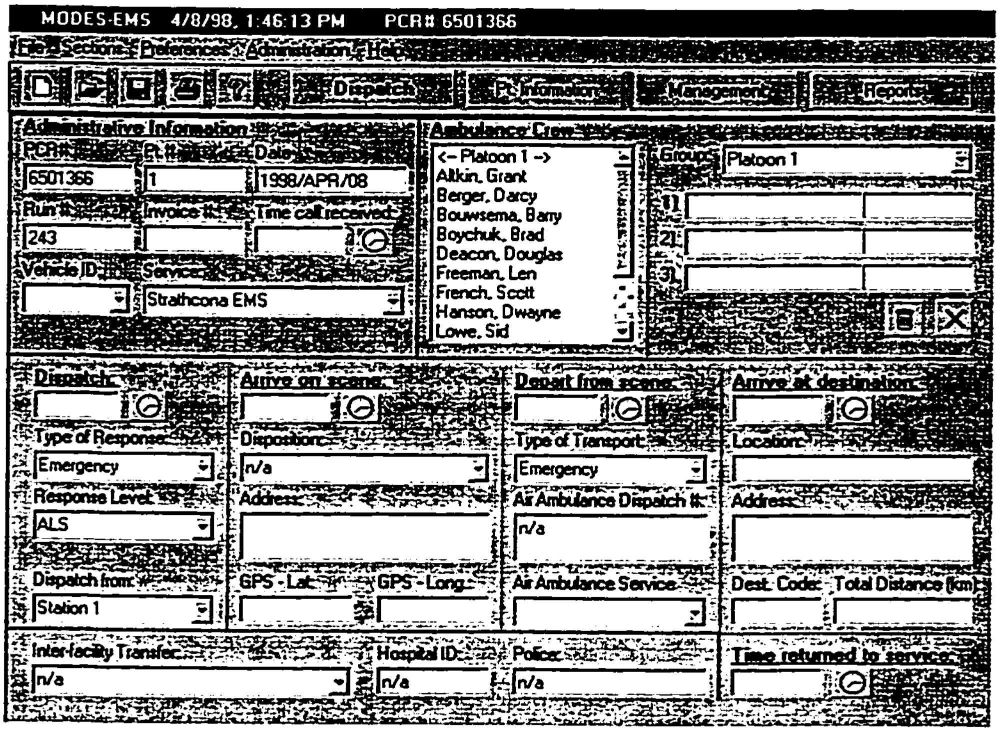


Figure 4.4 – MODES-EMS Patient Information screen

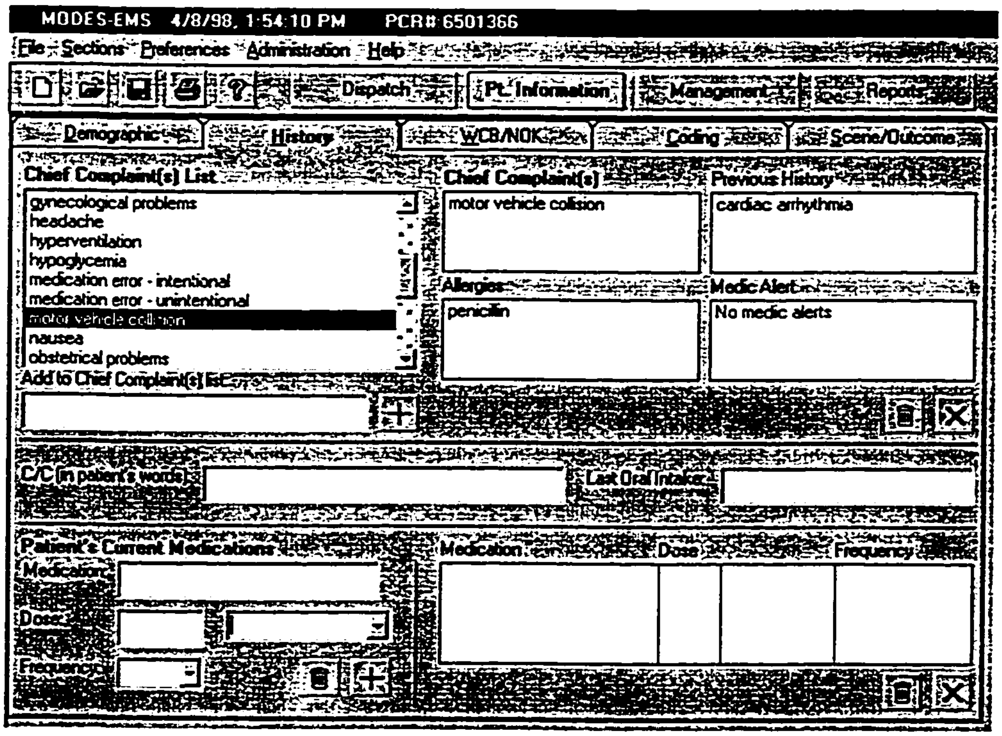


Figure 4.5 – MODES-EMS Patient Information Module: Demographic section

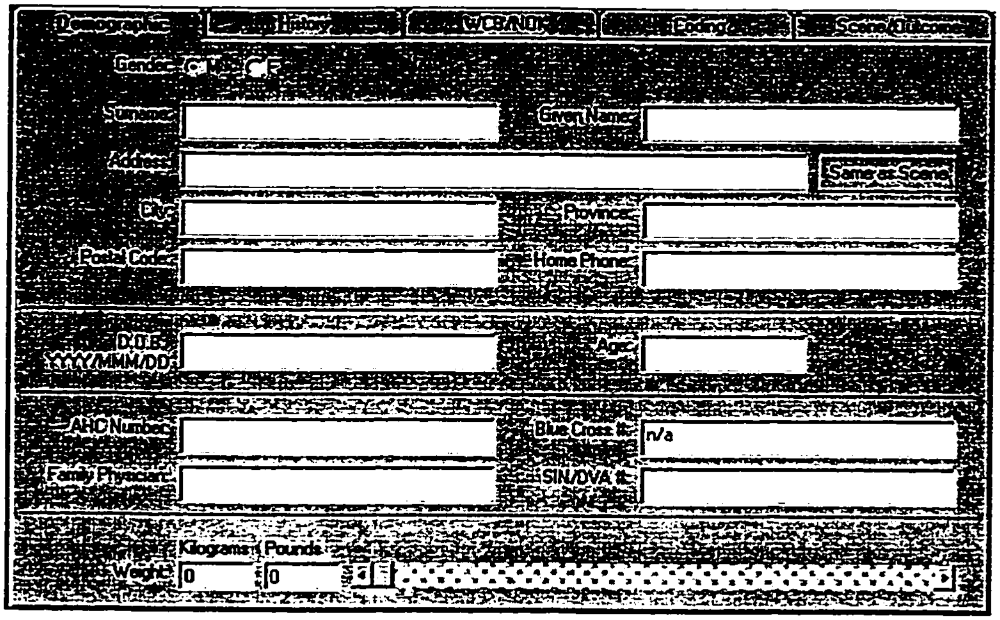


Figure 4.6 – MODES-EMS Patient Information Module: History section

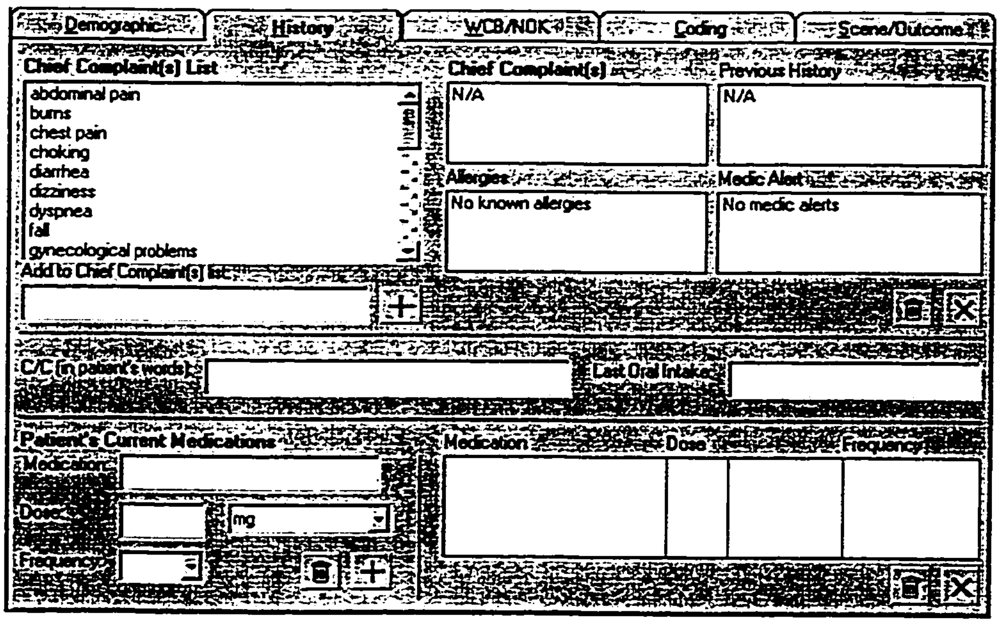


Figure 4.7 – MODES-EMS Patient Information Module: WCB/NOK section

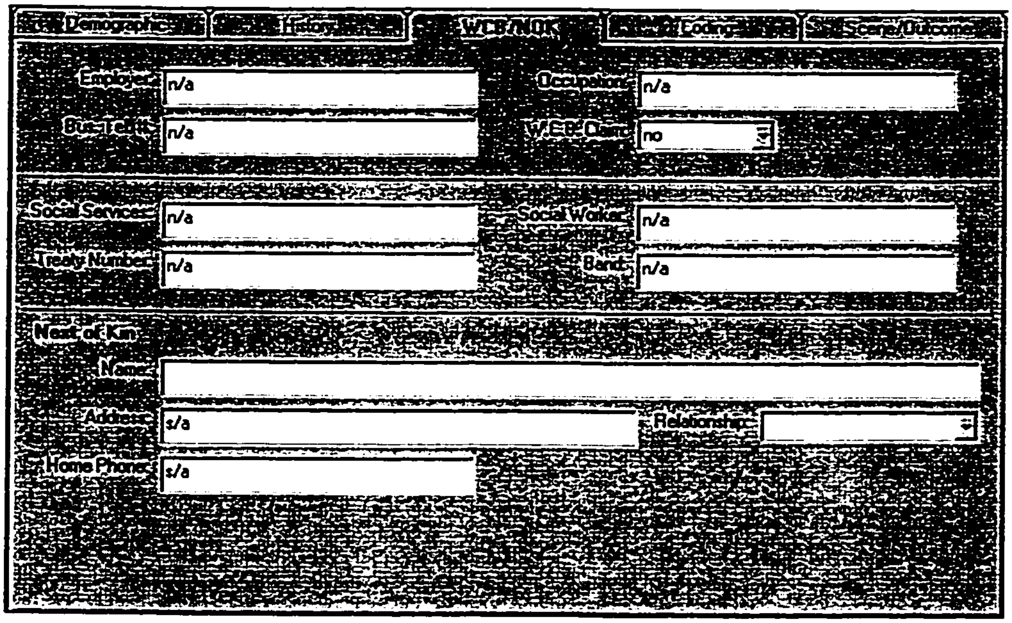


Figure 4.8 – MODES-EMS Patient Information Module: Coding section

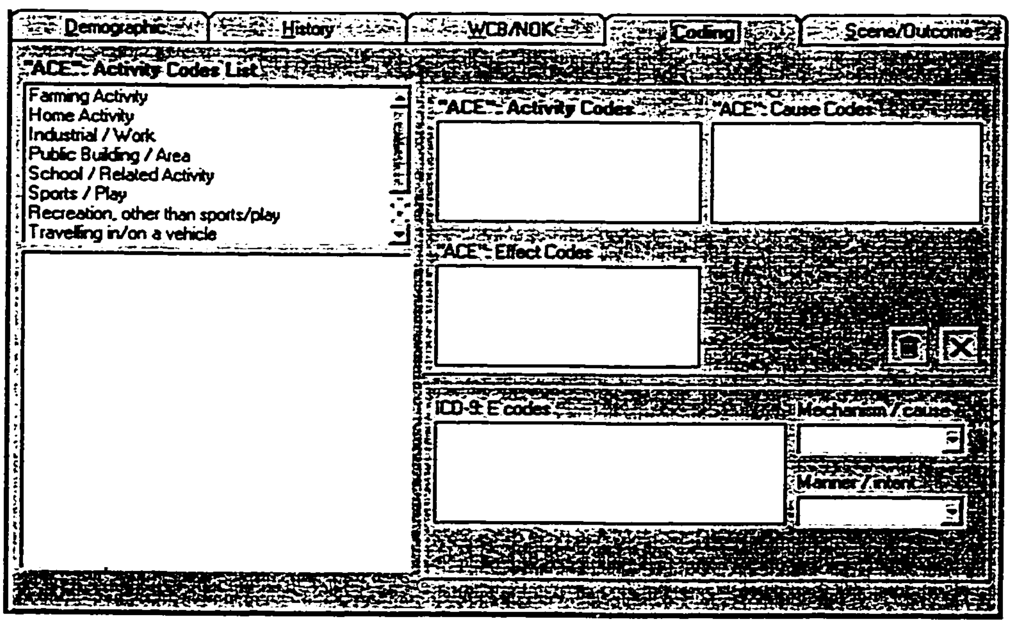


Figure 4.9 – MODES-EMS Patient Information Module: Scene/outcome section

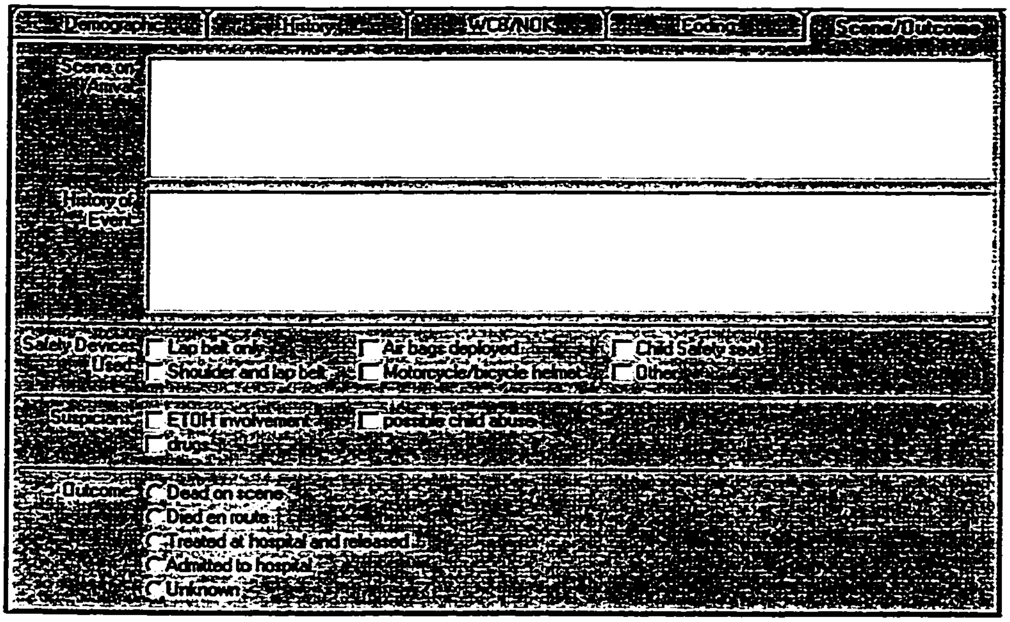
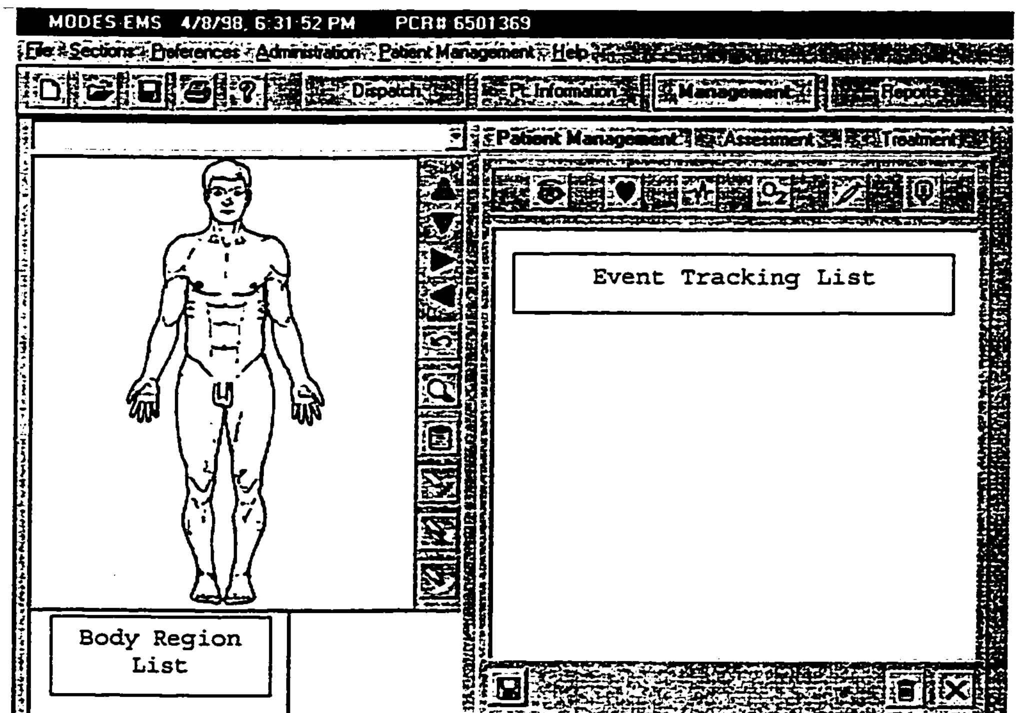


Figure 4.10 – MODES-EMS Patient Management Screen



Patient Management Section Icons

Observations
Vital Signs
EKG readings
Oxygen
I.V.
Medications

Body Region Image Control Icons

Anterior/posterior view | Magnify region | Patient management mode
Illustrate mode | Erase segment | Erase entire illustration

Figure 4.11 – Assessment sub-section

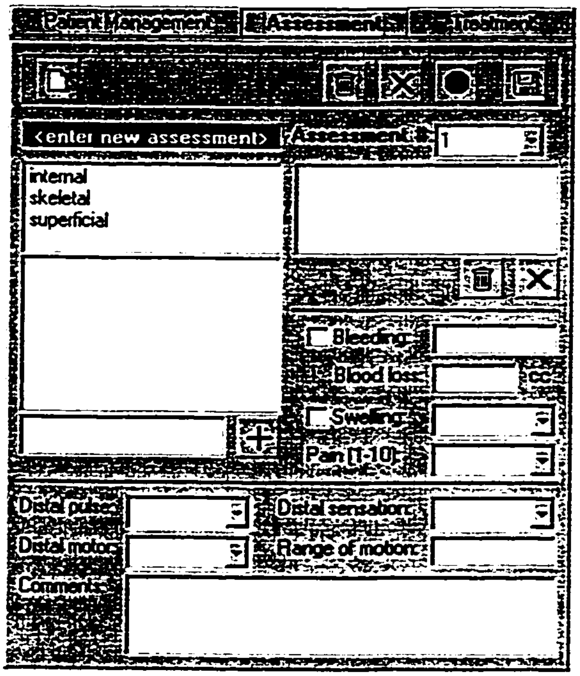


Figure 4.12 – Treatment sub-section

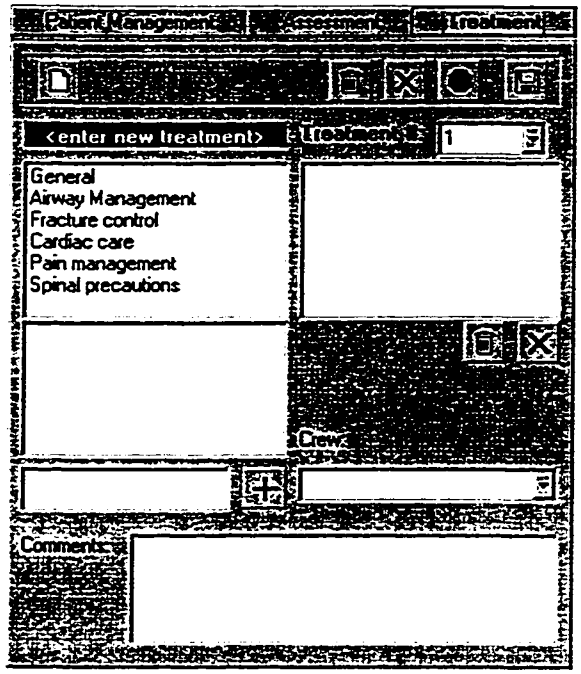


Figure 4.13 – MODES-EMS Observations Screen

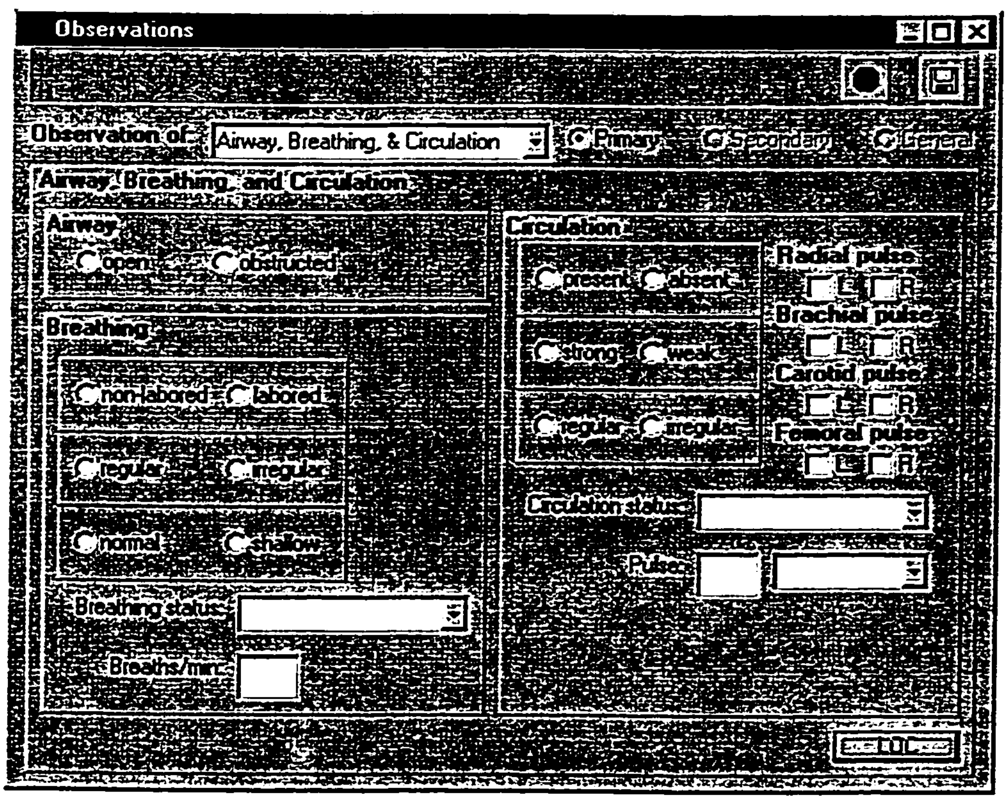


Figure 4.14 – MODES-EMS Vital Signs Screens

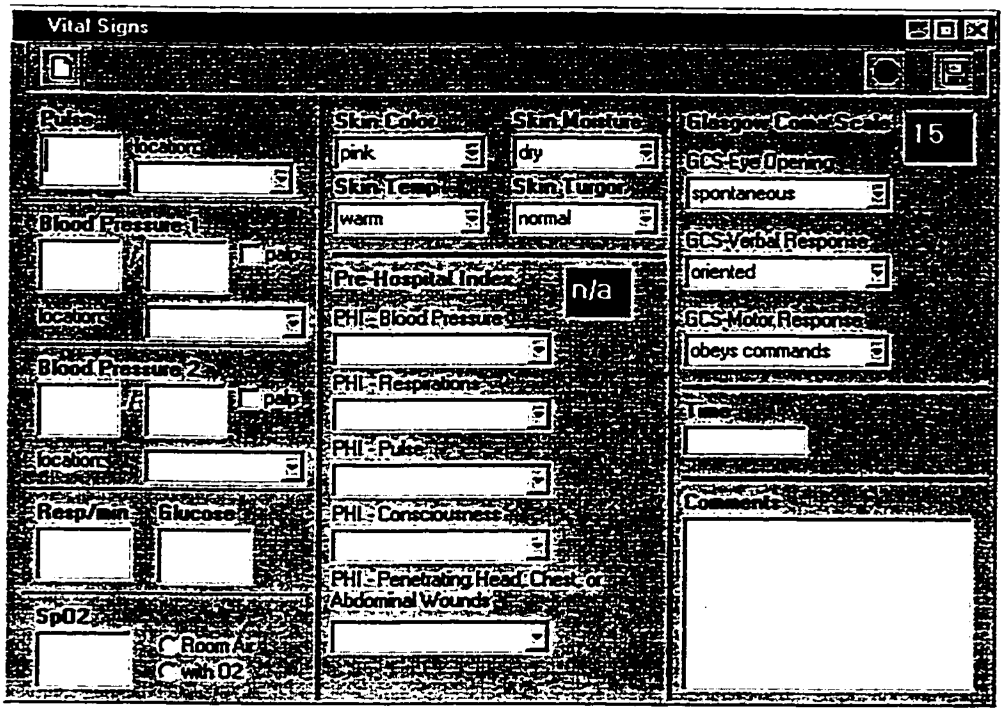
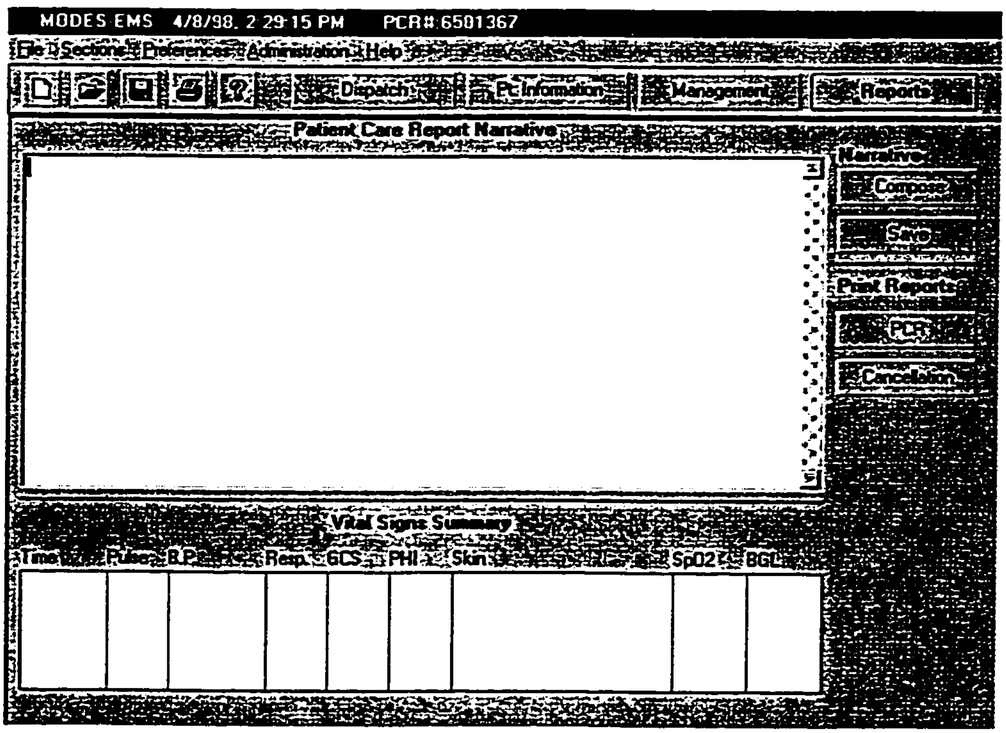


Figure 4.15 – MODES-EMS Reports Screen



4.4 References

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Chapter 5

Conclusion and Future Directions

This thesis describes the design, development, and implementation of a computerized injury surveillance system based on emergency medical services data. This prototype system provides the framework for development of future injury surveillance modules and is the first step towards providing injury researchers accurate, timely, and readily available injury data in electronic format.

The work described in this thesis draws upon the methods and knowledge of two fields, epidemiology and health informatics, and combines the two in the formation of a work that can, hopefully, serve as a model for the development of similar systems. The major contributions of the research outlined in this thesis can be described as follows:

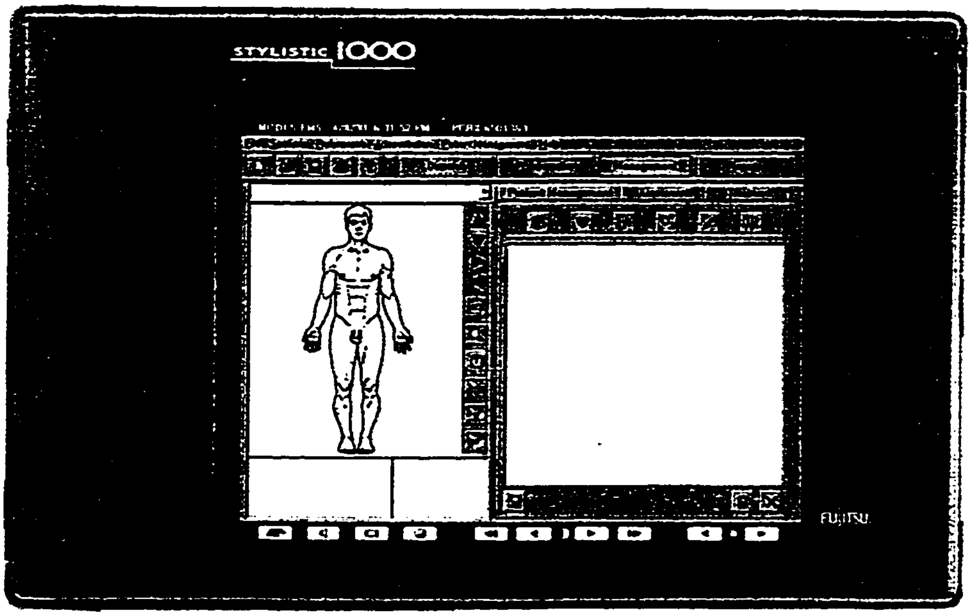
- The definition of a core injury surveillance data set that forms the basis of the EMS-based injury surveillance system described in this work and will be the foundation for additional injury surveillance modules in the future.
- The definition of an operationally-effective data set for the EMS environment encompassing a patient encounter model and a clinical data set.
- An analysis of the requirements of two focus groups, EMS and data users, to develop a software package that functions as an effective patient management tool for EMS personnel and is able to collect and export data necessary for injury surveillance and research. Based on the requirements analysis, a software program, MODES-EMS, was developed to be used in the field by EMTs and paramedics as a patient management and injury data collection tool.

- The adaptation of the new ICD-9-CM E-code matrix into a system for quickly and easily entering E-codes from a pick-list.
- Based on the data entered into the software program from previously completed patient care reports, an analysis was performed of the patterns of injury in Strathcona County, Alberta. The demographic and injury data from the study roughly reflect the general Alberta trends for the occurrence of injury.

This work is only the first step in the development of a large-scale, comprehensive, and population-based injury surveillance system. Once other modules are developed and data from different sources are linked, injury researchers will finally have the tools to better understand where, when, to whom, and why injuries are occurring. Armed with this knowledge, researchers will be better able to coordinate the prevention, EMS, acute care, and rehabilitation aspects of injury control, to evaluate the effectiveness of education, legislation, and engineering interventions, and to study the costs, both direct and indirect, of injury on society.

Appendix A

Hardware Specifications



Fujitsu Stylistic 1000 Specifications

Form Factor	small tablet size, pen-based computer
Overall Dimension	7.3" x 11.0" x 1.6"
Weight (with battery)	3.5 lbs
Architecture	IBM PC-AT compatible
Microprocessor	AMD Am486 DX4, 100 MHz
System Memory	8MB DRAM standard, upgradeable to 24MB
BIOS	512KB Flash ROM
Operating System	Microsoft Windows 95

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6″

APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989