# FIVE-YEAR SURVIVAL OF GERIATRIC PATIENTS FOLLOWING TRAUMA CENTER DISCHARGE

By

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#### Abstract

#### Introduction

Traumatic injury is the seventh leading cause of death in the geriatric population. High in-hospital case fatality rates have been well documented yet little is known about the long-term effects of injury on seniors who survive to trauma center discharge. Previous investigations have identified an ongoing mortality risk in the months and years following injury but few have compared subjects' mortality rates to population-based norms. Aim 1 of this study was to quantify the influence of injury on geriatric patients' five-year survival, compared to each patient's projected life expectancy, based on actuarial norms. A second aim was to examine the relationship between five-year survival and various patient and injury characteristics, present at the time of hospital discharge, in order to identify variables associated with increased risk of death.

## Methods

The primary data source for this retrospective, population-based cohort design study was all patients entered into the Oregon Trauma Registry between 1992 and 2000, who were 65 years of age or older at the time of injury, and who were discharged alive. Subjects' records were cross-linked with the National Death Index to ascertain vital status and age at death. Total sample size was 3,633. For the 1,970 subjects injured between 1997 and 2000, expected age at death was determined by assigning hypothetical, age, race, and gender matched controls derived from the U.S. Life Tables. For Aim 1, Cox proportional

hazards model was used to determine hazard ratios for death in 1,970 subjects versus controls within five years of injury. For Aim 2, all 3,633 subjects were entered into bivariate and multivariate Cox proportional hazards models to identify pre-injury, injury, and post-injury variables associated with life expectancy in geriatric trauma survivors.

# Results

The all cause hazard for death in injured subjects was 6.26 times that of controls (males 7.42, females 5.31). Of the pre-injury, injury, and post-injury variables tested, only gender, age at the time of injury, preexisting systems dysfunction, location of injury occurrence, discharge disposition, and discharge limitations score predicted five-year vital status in the final, multivariate model. Injury Severity Scores did not predict long-term survival. Compared to those injured on roadways, persons injured in a residential institution had a hazard ratio of 3.07; those injured at farm/logging/industrial sites experienced a hazard ratio of 0.48. Compared to a home discharge location, the 5-year mortality hazard for subjects discharged to a skilled nursing facility was 1.24; 1.68 for those discharged to an acute care facility.

### Discussion

This was the first large-scale study to employ actuarial data to identify the increased long-term burden of mortality on geriatric trauma survivors—across all injury types, mechanisms, and severities—in order to provide a comprehensive perspective of post-trauma outcomes in a state with an inclusive and well-established trauma system.

Two key findings were evident. There is a quantifiable, ongoing, long-term (five year) relationship between trauma and shortened lifespan in geriatric Oregon Trauma Registry survivors. The second key finding was that this long-term relationship between trauma and death is largely influenced by host factors (pre- and post-injury patient status), rather than by factors directly associated with the injuring event.

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#### Chapter 1—Introduction

#### Background

Longevity gains and increasingly active lifestyles have made traumatic injury the seventh leading cause of death in older adults in the United States. The serious consequences of injury on geriatric in-hospital mortality have been well documented. Following major trauma, individuals over the age of 65 experience an in-hospital death rate two-to-six times greater than their similarly-injured-but-younger counterparts. However, this traditional focus on inpatient mortality, as a measure of both patient and trauma system outcomes, inadequately describes seniors' experience with injury. Research that relies on survival status at hospital discharge to quantify risk of death assumes that injured patients, discharged alive, will immediately return to the same mortality risk demonstrated by the general population. Yet, a variety of previous investigations have documented that elderly individuals remain at risk for death in the weeks, months, and even years post-injury.

Most analyses of geriatric trauma mortality include only patients who die during hospitalization and exclude individuals whose premature demise is influenced by their antecedent injuries. The consequences of trauma in the elderly are thus grossly underestimated, creating a substantial gap in the knowledge about these patients and how injury affects life expectancy. To date, no published study has examined long-term survival in elderly individuals—across the spectrum of injury types and injury severityon a systemwide basis, in a state with a well-coordinated and well-established trauma care system.

The objective of this retrospective, population-based cohort study was to quantify the influence of injury on geriatric patients' five-year survival, compared to each patient's projected life expectancy. An additional aim was to examine the relationship between five-year survival and various patient and injury characteristics present at the time of trauma center discharge, in order to identify variables associated with increased risk of death. The initial outcome variable of interest was the five-year vital status (dead or alive) of persons aged 65 years or older at the time of traumatic injury, who were discharged alive from a trauma care facility within the Oregon Trauma System.

Predictor variables of interest included both patient and injury characteristics that are associated with five-year survival. Patient variables extant at the time of injury—and shown by other researchers to be related to survival—were age, gender, and pre-existing medical conditions. Injury variables of interest were mechanism of injury, location of injury occurrence, and Injury Severity Score. Patient variables present upon discharge included intensive care unit and non-intensive care unit lengths of stay, discharge disposition, and functional status at discharge. Data on these variables were retrieved from the Oregon Trauma Registry. Date of death was identified from the National Death Index and the Social Security Death Index. Predicted remaining life expectancy was determined by U.S. Life Tables.

# Significance

Geriatric in-patient mortality following trauma has been well documented. A number of previous investigations have examined short-term (less than one year) and intermediate term (1-to-4 year) survival in injured older adults, but few have looked at the impact of trauma on long-term ( $\geq$  5 years) survival. Only a small number of studies have compared the incidence of death in injured seniors—which is inherently high among the older adults—to that of matched controls. And, although Medicare data have been used to examine long-term survival, no researcher has looked specifically at statewide outcomes, in a state with a long-standing, comprehensive system for providing trauma patient care.

By tracking vital status for five years following injury, this study describes the effect of key patient and injury variables on geriatric post-trauma survival. Baseline information about the long-term effects of injury on elderly survivors will enable researchers and clinicians to compare outcomes between settings and evaluate the impact of interventions designed to reduce post-injury mortality. Patients, family members, clinicians, health care systems, payors, and policy makers can use these data to more effectively and realistically address the long-term needs of injured older adults and target interventions designed to improve post-trauma survival and quality of life for elderly individuals.

## Chapter 2—Review of the Literature

#### *Review of the Literature*

A mounting body of evidence suggests that the current trauma center emphasis on hospital survival, as an indicator of both patient and trauma system success, does not capture the older adults' experience. Major trauma appears to shorten lifespan in discharged elderly trauma patients compared to population-based life expectancy norms. This section will address the scope of the growing geriatric trauma problem, explore common mechanisms of injury and their effect on aging individuals, describe the status of trauma system development in the U.S., and review the current state of the science regarding outcomes following injury in the elderly.

## The Growing Geriatric Population

Older adults constitute the fastest growing segment of the U.S. population. Currently, there are 36 million Americans over the age of 65 years, representing 12% of the population. Six percent are more than 75 years old. In 2020, the number of senior citizens in this country is expected to total 71.5 million. By 2050, there will be a projected 86.5 million Americans over the age of 65, accounting for 21% of the entire population. And, unprecedented in the history of the world, 12% of the population will be 75 years or older (National Center for Health Statistics, 2005). The anticipated demands on the health care system associated with providing for the medical needs of seniors will be staggering. In the year 2030, an estimated 9 million Americans over the age of 85 will require hospitalization (Mann, Cahn, Mullins, Brand, & Jurkovich, 2001). These projected demographic changes are not limited to the United States. Similar trends are anticipated in most of the developed world (L. Young & Ahmad, 1999).

## The Growing Geriatric Trauma Population

Both longevity gains and active lifestyles have contributed to rising injury frequency among older adults (Callaway, Wolfe, Callaway, & Wolfe, 2007; Lane, Sorondo, & Kelly, 2003; Marciani, 1999; Rzepka, Malangoni, & Rimm, 2001) In 1900, life expectancy at age 65 was just under 12 years. By 2002, life expectancy at 65 had climbed to 18.6 years (National Center for Health Statistics, 2006a). This trend toward increased longevity is expected to continue. Trauma, once considered predominately a disease of the young, has long been the primary cause of death for Americans between the ages of 1 and 44 years. Although the incidence of major traumatic injury remains lower in the geriatric population than in any other age group, the overall incidence is highest among seniors. The all-cause injury rate for Americans over the age of 65 is 288 per 10,000 population, whereas the rate in all other age groups ranges from 38.6-to-90.3 per 10,000 (Hall & Owings, 2000) (Table 2-1).

Over the past few decades, prevention efforts (such as seat belt and helmet laws) have substantially reduced the number and severity of injuries in younger individuals. Similar reductions have not been achieved among the older population (Hoskin, 2000; Shinoda-Tagawa & Clark, 2003; Wolinsky, Fitzgerald, & Stump, 1997). Hannan and colleagues examined New York State Trauma Registry records for the five-year period between 1994 and 1998. They noted a drop in the total number of injured 13-to-39-yearolds. During the same time period the incidence of injury increased by 17.6% in the 75to-84 year-old age group, and by 16.4% among patients over the age of 85 years (Hannan, Waller, Farrell, & Rosati, 2004). Traditionally, seniors have not been the target of major injury prevention initiatives. In addition, behavioral changes—the focus of many preventative efforts—are more effective in younger individuals than in elders who are less likely to engage in the sort of high risk activities amenable to behavior modification. Most injuries in older adults, such as falls and auto versus pedestrian incidences, occur during the course of routine activities of daily living.

Because of these trends, geriatric trauma patients now constitute the fastest growing segment of the population treated in trauma centers (Mann et al., 2001). In some areas of the country, the number of older women hospitalized for injury currently exceeds that of young men (Clark & Chu, 2002; Hall & Owings, 2000; Richmond, Thompson, Kauder, Robinson, & Strumpf, 2006). Researchers at the Mayo Clinic have reported that 31% of their trauma patients are now over the age of 65, and the mean age of this group is 79 years (Zietlow, Capizzi, Bannon, & Farnell, 1994).

Trauma—both intentional and unintentional injury—is the third leading cause of fatalities in the United States and the seventh most common cause of death for Americans over 65 years old. The incidence of trauma-related mortality in this older group is exceeded only by deaths from cardiovascular disease, malignancies, respiratory disorders, Alzheimer's disease, and diabetes mellitus (National Center for Injury Prevention and Control, 2003) (Table 2-1).

	U.S.	Oregon	U.S.	U.S.	Oregon	U.S.	Oregon	U.S.	Oregon
	All Ages	65	5+	65	-74	75-	75-84		5+
1	Heart Disease	Malignant Neoplasms	Heart Disease	Malignant Neoplasms	Malignant Neoplasms	Heart Disease	Malignant Neoplasms	Heart Disease	Heart Disease
I	685,089	7,232	563,390	141,248	1,806	207,331	2,211	248,796	2,760
2	Malignant Neoplasms	Heart Disease	Malignant Neoplasms	Heart Disease	Heart Disease	Malignant Neoplasms	Heart Disease	Malignant Neoplasms	Malignant Neoplasms
-	556,902	7,049	388,911	107,263	1,041	167,617	2,118	80,046	1,203
3	Traumatic Injury	Cerebro- vascular	Cerebro- vascular	COPD	COPD	Cerebro- vascular	Cerebro- vascular	Cerebro- vascular	Cerebro- vascular
0	<mark>15,8445</mark>	2,554	138,134	29,919	443	52,847	869	64,579	1,157
4	Cerebro- vascular	Traumatic Injury	COPD	Cerebro- vascular	Cerebro- vascular	COPD	COPD Resp Dx	Alzheimer's Disease	Alzheimer's Disease
	157,689	<mark>1,993</mark>	109,139	20,708	315	49,286	717	37,821	723
_	COPD	COPD	Diabetes Mellitus	Diabetes Mellitus	Diabetes Mellitus	Diabetes Mellitus	Alzheimer's Disease	Influenza/ Pneumonia	COPD
0	126,382	1,819	54,919	16,656	195	23,299	367	31,397	416
	Diabetes Mellitus	Alzheimer's Disease	Influenza/ Pneumonia	<mark>Traumatic</mark> Injury	Traumatic Injury	Alzheimer's Disease	Diabetes Mellitus	COPD	Influenza/ Pneumonia
U	74,219	1,157	57,670	<mark>10,436</mark>	<mark>136</mark>	21,157	340	29,934	344
7	Influenza/ Pneumonia	Diabetes Mellitus	Alzheimer's Disease	Nephritis	Alzheimer's Disease	Influenza/ Pneumonia	Traumatic Injury	Diabetes Mellitus	Traumatic Injury
'	65,163	1,032	58,978	7,345	59	19,442	<mark>234</mark>	14,964	<mark>267</mark>
8	Alzheimer's Disease	Influenza/ Pneumonia	Traumatic Injury	Influenza/ Pneumonia	Liver Disease	Traumatic Injury	Influenza/ Pneumonia	Nephritis	Diabetes Mellitus
0	63,457	632	<mark>38,805</mark>	6,831	55	<mark>15,223</mark>	169	13,816	211
٩	Nephritis	Liver Disease	Nephritis	Septicemia	Influenza/ Pneumonia	Nephritis	Parkinson's Disease	Traumatic Injury	HTN
3	42,453	375	35,254	5,970	51	14,093	156	<mark>13,146</mark>	160
10	Septicemia	HTN	Septicemia	Liver Disease	Nephritis	Septicemia	Nephritis	Septicemia	Athero- sclerosis
10	34,069	351	26,445	5,406	49	10,932	117	9,543	111

Table 2-1. Leading Cause of Death in Older Age Groups; United States, 2003

HTN = Hypertension; COPD = Chronic obstructive pulmonary disease

Centers for Disease Control, National Injury Prevention Center, WISQARS<sup>TM</sup> (Web-based Injury Statistics Query and Reporting System) http://www.cdc.gov/ncipc/wisqars/

In 2003, nearly 2.7 million injuries to U.S. seniors ( $\geq$  65 years) were reported. Eighteen percent of these patients required hospitalization and there were a total of 40,728 trauma deaths (National Center for Injury Prevention and Control, 2003). Once injured, the consequences of trauma in the elderly are significant. Although only 10% of U.S. emergency department visits for injuries involve persons over the age of 65 years, approximately 25% of all trauma-related fatalities occur in this group (National Center for Injury Prevention and Control, 2003) (Figure 2-1).





Centers for Disease Control, National Injury Prevention Center, WISQARS<sup>TM</sup> (Web-based Injury Statistics Query and Reporting System) http://www.cdc.gov/ncipc/wisqars/

In Oregon, the proportion of injured older adults has climbed steadily. When tracking began in 1992, only 9% of patients in the Oregon Trauma Registry were over the age of 65. By 2004, seniors represented 13% of all Oregon Trauma System patients. This increase occurred largely among the oldest segment of the population. Between 1992 and 2004, the number of injured individuals over the age of 75 increased 350% (Figure 2-2) (Oregon Emergency Medical Services and Trauma Systems, 2006).





Oregon Trauma Registry Statistics, 1992-2004

# Defining the Geriatric Trauma Patient

One issue confounding analysis of the geriatric trauma patient is the lack of a standardized definition of what constitutes "elderly" in this context. Both physiologically and statistically, it is difficult to characterize patients merely as "old" or "young". A 2003 study of almost 200,000 trauma patients found an increased relative mortality rate starting at the age of 40 years (J. Morris, MacKenzie, & Edelstein, 1990; Victorino, Chong, & Pal). Hannan and colleagues (2004) conducted a five-year review of over 63,000 blunt trauma cases. Using 13-to-39 year-old patients as their reference group, these researchers identified the following odds ratios (OR) for in-hospital death in older cohorts: 40-to-64 years, 2.67; 65-74 years, 8.41; 75-84 years, 17.40; and 85 and up, 34.98. Grossman and colleagues (2002) calculated that in-hospital deaths in trauma patients increased by 6.5% for every year of age above 65. And, U.S. injury statistics for 2003 show a crude mortality rate that rises steadily with age from a low of 6.3 deaths per 100,000 injured in the 5-to-9 year-old age group, to 299 per 100,000 in persons beyond 85 years (Table 2-2).

Although the majority of researchers have selected the U.S. Census definition of 65 years as a cutoff point, other definitions of "old" or "elderly" used in trauma research include 40 (Hannan et al., 2004), 50 (Forsen, Sogaard, Meyer, Edna, & Kopjar, 1999; Kannus, Niemi, Palvanen, & Parkkari, 2000), 55 (Albaugh et al., 2000; Brotman et al., 1991; Kai-tak, Harding, Jarvis, & Werner, 2006; Rogers et al., 2001), 60 (Demetriades et al., 2004; Pennings, Bachulis, Simons, & Slazinski, 1993; Taheri et al., 1997; van der Sluis, Klasen, Eisma, & ten Duis, 1996), 64 (Gan, Lim, & Ng, 2004; Peek-Asa,

Age Group	Number of Deaths	Crude Rate	
0-4	3 485	19 769 279	17.63
5-9	1 240	19,705,276	6 27
-5 10-14	2,000	21 103 361	0.27
15-14	2,009	21,193,301	50.62
15-19	10,509	20,478,409	30.03
20-24	14,916	20,727,694	71.96
25-29	11,540	19,167,954	60.20
30-34	11,552	20,704,644	55.79
35-39	12,841	21,408,004	59.98
40-44	15,335	22,962,590	66.78
45-49	14,375	21,761,188	66.06
50-54	11,279	19,043,411	59.23
55-59	8,252	15,794,050	52.25
60-64	5,939	12,105,686	49.06
65-69	5,181	9,746,083	53.16
70-74	5,804	8,590,961	67.56
75-79	7,270	7,452,593	97.55
80-84	8,373	5,416,079	154.60
85+	14,100	4,713,467	299.14
Totals	163,860	290,810,789	56.35
Т	otal trauma deaths in pe	erson 65+ years	40,728
Percent	25%		

Table 2-2. Number and Crude Rate of Post-Injury Deaths, All Age Groups; United States, 2003

Centers for Disease Control, National Injury Prevention Center, WISQARS<sup>TM</sup> (Web-based Injury Statistics Query and Reporting System) http://www.cdc.gov/ncipc/wisqars/

(Gan, Lim, & Ng, 2004; Peek-Asa, Dean, & Halbert, 1998; Scheetz, 2003), 67 (Gubler et

al., 1997; Gubler et al., 1996), 70 (Demetriades et al., 2001; McGwin, May, Melton,

Reiff, & Rue, 2001; Oreskovich, Howard, Copass, & Carrico, 1984; Wolinsky et al.,

1997), 75 (Battistella, Din, & Perez, 1998; Empana, Dargent-Molina, & Breart, 2004) or

even 80 years (Meldon, Reilly, Drew, Mancuso, & Fallon, 2002).

## Defining Trauma in the Geriatric Population

A second basic issue confounding the study of geriatric trauma involves the definition of injury. A generally accepted research definition of acute traumatic injury is: all patients with one or more International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) discharge diagnosis codes within the 800-959.9 range. However, codes commonly excluded from this group of diagnoses by investigators are: 905 to 909 (late effects of injury), 910 to 924 (blisters, contusions, abrasions, and insect bites), 930 to 939 (foreign bodies), and 958 (complications of injury) (American College of Surgeons, 2005; Cameron, Purdie, Kliewer, & McClure, 2005a; MacKenzie et al., 2006; Mann et al., 2001; Mullins, Mann, Hedges, Worrall, Helfand et al., 1998; Sartorelli et al., 1999; Zimmer-Gembeck et al., 1995). Some researches also exclude older adults with isolated hip fractures—related to a same-level fall—because both the population and mechanism of injury differ considerably from those of patients involved in multisystem trauma (Richmond, Kauder, Hinkle, & Shults, 2003). More recent investigations have employed the updated ICD-10-CM codes. Although the actual code numbers have changed, the conditions included in the definition of trauma remain the same.

## The Injury Severity Score.

(ISS) is the classification system most widely used to quantify the extent of injury and

facilitate comparison among patients with varying trauma mechanisms. This retrospectively calculated score allows researchers to compare the extent of a patient's wounds, regardless of injury mechanism (Stephenson, Henley, Harrison, & Langley, 2004). To obtain the ISS, injuries are rated 1 to 6 (minor to unsurvivable) on the Abbreviated Injury Scale (AIS). A separate AIS score is determined for injuries to each of six body regions: the head, face, chest, abdomen, extremities, and external surfaces. Next, the highest AIS scores from the three most severely injured regions are selected. These numbers are each squared then summed to produce the final ISS. Possible Injury Severity Scores range from 0 to 75. If any injury is classified as an AIS of 6 (unsurvivable), an ISS of 75 is automatically assigned without further calculation (Frutiger, 1997).

Regrettably, there is no universally accepted definition of what ISS scores constitute various injury severity levels. An ISS of 15 or less has been used by many including the Oregon Health Division—to define minor trauma, while a score greater than 15 is commonly used to denote serious injury (Bazzoli, Madura, Cooper, MacKenzie, & Maier, 1995; Cameron, Purdie, Kliewer, & McClure, 2005b; Demetriades et al., 2006; Gallagher et al., 2003; MacKenzie et al., 2006; Mann et al., 2001; McKevitt et al., 2003; Mullins, Mann, Hedges, Worrall, & Jurkovich, 1998; Olson et al., 2001; Oregon Emergency Medical Services and Trauma Systems, 2006; Scheetz, 2003; Taylor, Tracy, Meyer, Pasquale, & Napolitano, 2002; Zimmer-Gembeck et al., 1995)

Because the ISS has a possible total of 75 points, a number of researchers have rejected simply dichotomizing the ISS at a score of 15. Several investigators have instead

categorized scores as Mild (ISS < 15), Moderate (ISS 15-30), and Severe (ISS > 30) trauma (Bergeron et al., 2003; Grossman et al., 2002; Taylor et al., 2002). Meldon and colleagues (2002) stratified their elderly patients into five ISS groups (0-10, 11-15, 16-20, 21-45, and 46-57) and considered any number above 20 to be indicative of "severe" trauma. Richmond (Richmond et al., 2003) used a similar scheme but capped "severely injured" at any score beyond 25. In a study specific to geriatric patients, Grossman and colleagues stratified ISS as Low ( $\leq$  10), Medium (11-20), and High (> 20) (Grossman et al., 2003). And, the National Trauma Data Bank categorizes Injury Severity Scores from 0-to-9 as Minor; 10-to-15 as Moderate; 16-to-24 as Severe; and greater than 24 as Very Severe (American College of Surgeons, 2005).

Another factor confounding the use and interpretation of ISS in trauma research is the marked score variability between patient cohorts. The mean Injury Severity Score reported in the geriatric trauma patient studies reviewed ranged widely, from 9.4 to 33.2 (Battistella et al., 1998; Broos, Stappaerts, Rommens, Louette, & Gruwez, 1988; DeMaria, Kenney, Merriam, Casanova, & Gann, 1987; Gallagher et al., 2003; Hui, Avital, Soukiasian, Margulies, & Shabot, 2002; McKevitt et al., 2003; Richmond et al., 2003; Schiller, Knox, & Chleborad, 1995; Tornetta et al., 1999; Zietlow et al., 1994)

Simply dichotomizing patients as minor or major trauma, based on an ISS of 15, may not adequately reflect risks to older adults. In an early review of patients with low severity scores, Brotman and colleagues (1991) studied persons (all ages) admitted to 28 trauma centers to identify those with a low ISS. Of the 3,594 patients treated during one three-month period, 50.8% had a score below ten. Outcomes for 95% of this group were good, begging the question of whether individuals with such low injury scores should be transported to trauma centers and included in trauma registries. However, analysis of the ten low-scoring non-survivors, showed that half were over the age of 55 years, as were 61% of the low-scorers seriously disabled by their injuries. These investigators concluded that, because of significant risk of death and disability, it is appropriate to include elderly patients with a low ISS (< 10) in the trauma registry if they meet other inclusion criteria. Conversely, Demetriades' group focused on geriatric patients ( $\geq$  70 years) with high injury severity scores. They noted that an ISS of 20—a number generally considered serious but not critical in the younger population—was associated with an alarming 68% in-hospital mortality in this older cohort (Demetriades et al., 2002).

Such findings have prompted several researchers to suggest that, in the elderly, any ISS greater than nine should be considered "serious" injury (Brotman et al., 1991; Perdue, Watts, Kaufmann, & Trask, 1998; Richmond et al., 2006; Shinoda-Tagawa & Clark, 2003). However, findings do not universally support this recommendation. In the largest review of elderly trauma patients ( $\geq 65$  years) to date, Grossman and colleagues reported that an ISS less than 15 was associated with an in-hospital mortality of only 3%, an ISS of 15-to-30 with a mortality of 18.3%, and an ISS greater than 30 with a mortality of 50%. This degree of discrepancy between study sites has not been satisfactorily explained and requires further research. Differences in injury scoring, trauma interventions, or patient populations may explain the inconsistent findings.

In the elderly, analysis of injury frequency and outcomes is confounded by the presence of age-related changes and comorbidities. It is often unclear whether a traumatic event is responsible for subsequent decline or if preexisting frailty actually triggered the injury. Whether or not a causal relationship exists, several studies of isolated, single-system trauma in older individuals have documented significant post-discharge mortality, even among individuals with an ISS of 9 or less. In patients with an isolated hip fracture (ISS = 9), Irwin (2004) noted a 60-day mortality of 9.7%, and one third of Rose and Maffuli's (1999) hip fracture patients died within one year of injury. Even an isolated distal radius fracture in an elderly patient has been shown to correlate with a significantly decreased lifespan. Rozental and colleagues found that the cumulative estimated survival at seven years in their cohort of 325 elderly radial fracture patients was only 57% compared to the expected value of 71% for the general U.S. population (Rozental, Branas, Bozentka, & Beredjiklian, 2002).

#### Undertriage of the geriatric patient.

The practice of excluding patients with a low Injury Severity Score from some trauma centers, trauma registries, and trauma studies has resulted in serious underestimation of the frequency of injury in the elderly population (Bergeron et al., 2006; Zietlow et al., 1994). For example, of the 18,115 trauma deaths among Pennsylvania residents aged 65 and older, from 1988 through 1997, only 22% of these fatally injured patients (3,990) were included in the statewide trauma registry (Sattin & Mullins, 2002).

Exclusion of injured seniors from trauma centers and registries is a function of currently accepted trauma team activation criteria. Each U.S. trauma system identifies an

approximately standardized list of physiologic criteria (e.g., blood pressure, heart rate, respiratory rate) and mechanism of injury criteria (e.g., amputation above the wrist or ankle, ejection from a moving vehicle, penetrating trauma to the head or torso) to determine if a patient merits trauma center transport and trauma team activation. To avoid undertriage and to provide a margin of safety, these criteria were deliberately selected to have a high sensitivity. Seriously injured children and young adults generally meet two or more trauma triage criteria. However, in older adults, physiologic parameters frequently fail to adequately reflect injury acuity. Demetriades and colleagues (2001) found that inhospital mortality among older patients ( $\geq$  70 years) who met just one trauma team activation criterion was 50%. Injured elders who failed to meet even a single criterion experienced a 16% mortality.

Scheetz's (2003) retrospective review of the 2000 New Jersey State Patient Discharge Database revealed an undertriage rate for young ( $\leq$  64 years) males and females of 8% and 12% respectively. But, in patients over the age of 65, the incidence of undertriage climbed to 18% (males) and 15% (females). A similar statewide study was conducted in Pennsylvania. Researchers found that 52.6% of elders with an ISS over 15 were transported to non-trauma facilities. The high incidence of undertriage among seniors could not be explained by differences in pre-hospital vital signs, body region injured, or population density (Lane, Sorondo, & Baez, 2001). Zimmer-Gembeck and colleagues (1995) reviewed the cases of over 26,000 trauma patients (all ages) in a statewide trauma system (Oregon) during a two and a half year period. Severely injured patients who were inappropriately admitted to a non-trauma hospital (undertriaged) were almost five and a half times more likely to be elderly (OR, 5.44).

Such numbers indicate that current trauma triage criteria poorly identify seniors at risk. This has prompted some authors to recommend that injured seniors be initially triaged as major trauma patients, at a much lower threshold than similarly injured younger patients, so that they can receive the benefits of a full trauma team activation at a designated trauma center (Demetriades et al., 2001; Finelli, Jonsson, Champion, Morelli, & Fouty, 1989; Rogers et al., 2001). Based on such observations, Demetriades and colleagues (2002) modified the trauma team activation criteria at their facility to automatically include any patient 70 years or older and introduced a protocol for aggressive monitoring and resuscitation. These practice changes were associated with a drop in geriatric in-hospital mortality, in their study population, from 53.8% to 34.2%, demonstrating that significant survival gains for elderly trauma patients are possible with early identification and targeted interventions.

## Mechanisms of Geriatric Injury

According to the National Center for Injury Prevention and Control, unintentional falls are the most common mechanism of non-fatal injury for all ages except for persons in the 15-to-34 year-old age group (Table 2-3). In the geriatric population, falls are also

				Age Grou	р		
		25-34	35-44	45-54	55-64	65+	All Ages
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	1	Struck by/	Fall	Fall	Fall	Fall	Fall
		Against					
		814,406	802,758	656,056	461,756	1,628,146	7,434,032
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	2	MV-Occupant	Struck by/				
			Against	Against	Against	Against	Against
		718,054	656,746	411,840	184,005	217,035	4,970,710
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	3	Fall	Overexertion	Overexertion	MV-Occupant	MV-Occupant	MV-Occupant
		706,512	655,272	377,397	182,050	197,431	3,354,553
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	4	Overexertion	MV-Occupant	MV-Occupant	Overexertion	Overexertion	Overexertion
		699,342	582,489	358,124	145,752	149,275	3,233,993
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
		Cut/Pierce	Cut/Pierce	Cut/Pierce	Cut/Pierce	Cut/Pierce	Cut/Pierce
×		465,147	427,281	272,633	140,244	111,758	2,364,651
an	_	Other Assault	Other Assault	Other Assault	Unintentional	Unintentional	Other Assault
Ra	5	Struck by/	Struck by/	Struck by/	Other Bite/	Other Bite/	Struck by/
		Against	Against	Against	Sting	Sting	Against
		295,879	240,276	104,493	59,217	83,554	1,294,597
	0	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	6	Other Bite/	Other Bite/	Other Bite/	Foreign Body	Other	Other Bite/
		Sting	Sting	Sting	37,010	Transport	Sting
		144,468	142,989	99,749		38,124	1,036,796
	7	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	1	Foreign Body	Foreign Body	Foreign Body	Other	Unknown/	Unknown/
					Transport	Unspecified	Unspecified
		127,895	122,461	69,743	33,479	36,994	789,390
	Q	Unintentional	Unintentional	Unintentional	Other Assault	Unintentional	Unintentional
	0	Unknown/	Unknown/	Fire/Burn	Struck by/	Foreign Body	Foreign Body
		Unspecified	Unspecified	50.404	Against	00.440	705 044
•		124,440	100,074	59,484	29,436	36,116	735,214
	٥	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
	9	Other	Fire/Burn	Unknown/	Fire/Burn	Fire/Burn	Pedal Cyclist
		I ransport	04 400	Unspecified	00.040	04.000	000 400
		95.862	91.488	50.208	28.013	21.688	000.403

# Table 2-3. Leading Mechanisms of Non-Fatal Injury, by Age

Centers for Disease Control, National Injury Prevention Center, WISQARS<sup>TM</sup> (Web-based Injury Statistics Query and Reporting System) http://www.cdc.gov/ncipc/wisqars/

	Age Group						
		65-69	70-74	75-79	80-84	85+	
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
	1	Fall	Fall	Fall	Fall	Fall	
		28,998	32,655	54,531	73,413	128,074	
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
	2	MV-Occupant	MV-Occupant	MV-Occupant	MV-Occupant	MV-Occupant	
		6,076	7,278	6,665	3,531	3,395	
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
	3	Struck by/	Struck by/ Against	Overexertion	Struck by/ Against	Struck by/ Against	
		2,257	1,673	3,039	2,283	2,598	
ank		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
	4	Other Transport	Pedestrian	Struck by/ Against	Overexertion	Unknown/ Unspecified	
		1,101	1,061	1,395	2,046	2,265	
	5	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
		Machinery	Overexertion	Other Transport	Unknown/	Overexertion	
		953	980	1,090	1,612	1,967	
Ř	6	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
		Poisoning	Unknown/Unspecifi ed	Unknown/Unspecifi ed	Foreign Body	Natural/Environme	
		932	724	805	1,172	1,399	
		Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	
	7	Unknown/	Other Specified	Inhalation/	Other Transport	Foreign Body	
		876	574	798	706	824	
		Unintentional	Unintentional	Unintentional	Unintentional	Other Assault	
	8	Overexertion	Foreign Body	Pedestrian	Other Specified	Struck by/ Against	
		843	540	657	659	656	
		Unintentional	Other Assault	Unintentional	Unintentional	Unintentional	
	9	Pedestrian	Struck by/ Against	Poisoning	Pedestrian	Other Specified	
		738	519	609	479	420	
		Unintentional	Unintentional	Other Assault	Self-harm	Unintentional	
	10	Foreign Body	Other Transport	Struck by/ Against	Poisoning	Other Transport	
		601	506	589	440	330	

# Table 2-4. Leading Causes of Injury-Related Hospitalizations, by Age

Centers for Disease Control, National Injury Prevention Center, WISQARS<sup>TM</sup> (Web-based Injury Statistics Query and Reporting System) http://www.cdc.gov/ncipc/wisqars/

the leading cause of injury-related hospitalization, accounting for 61% of trauma admissions (Fallon et al., 2006; Gowing, Jain, Gowing, & Jain, 2007; K. Johnson & Johnson, 2001; Sterling, O'Connor, & Bonadies, 2001) (Table 2-4).

Additionally, among those over 80 years old, falls are the primary cause of traumatic death (National Center for Injury Prevention and Control, 2003). The majority of falls (84%) occur at home and approximately 13% are attributed to some acute medical condition (Emergency Nurses Association, 2000). Many factors associated with aging contribute to the high incidence of falling in the older population. Dementia, decreased visual acuity, obesity, neurological and musculoskeletal impairments, gait and balance disturbances, and medication use can all be contributory factors. Mullins and colleagues reviewed the record of 1,912 patients (all ages) admitted for injuries, whose in-hospital death or death within 30 days of discharge was attributed to a non-traumatic cause. Accidental fall was the mechanism of injury in 87% of cases suggesting that, for many of these patients, falls were a symptom of significant preexisting disease and not the primary cause of decline (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998).

Until the age of 75, motor vehicle collisions are the primary mechanism of fatal injuries in the United States and the number of older drivers is on the rise (National Center for Injury Prevention and Control, 2003) (Table 2-5). It is projected that, by the year 2020, there will be 50 million elderly persons eligible to drive in the U.S. (Emergency Nurses Association, 2000; Margolis et al., 2002). Although the total number of miles driven annually decreases in persons over the age of 55, seniors have a motor vehicle crash rate second only to that of 16-to-25 year-old males. And, following a

	1150 Gloup					
	45-54	55-64	65-74	75-84	85+	All Ages
	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
1	MV Traffic	MV Traffic	MV Traffic	Fall	Fall	MV Traffic
	5,876	3,824	2,868	5,249	6,404	43,340
	Unintentional	Suicide	Unintentional	Unintentional	Unintentional	Unintentional
2	Poisoning	Firearm	Fall	MV Traffic	Unspecified	Poisoning
_	5,434	2,317	2,048	3,102	3,019	19,457
	Suicide	Unintentional	Suicide	Unintentional	Unintentional	Unintentional
3	Firearm	Poisoning	Firearm	Unspecified	Suffocation	Fall
	3,279	1,370	1,700	1,703	1,329	17,229
	Suicide	Unintentional	Unintentional	Suicide	Unintentional	Suicide
4	Poisoning	Fall	Unspecified	Firearm	MV Traffic	Firearm
	1,567	1,220	622	1,595	1,309	16,907
	Homicide	Suicide	Unintentional	Unintentional	Suicide	Homicide
5	Firearm	Poisoning	Suffocation	Suffocation	Firearm	Firearm
	1,110	711	608	1,238	559	11,920
	Suicide	Suicide	Adverse	Adverse	Adverse	Suicide
6	Suffocation	Suffocation	Effects	Effects	Effects	Suffocation
	1,086	495	534	794	530	6,635
	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
7	Fall	Suffocation	Fire/burn	Fire/burn	Fire/burn	Unspecified
	1,043	445	429	480	274	6,630
	Undetermined	Unintentional	Unintentional	Unintentional	Unintentional	Unintentional
8	Poisoning	Fire/burn	Poisoning	Poisoning	Other	Suffocation
	999	400	403	284	229	5,579
	Unintentional	Homicide	Suicide	Suicide	Unintentional	Suicide
9	Fire/burn	Firearm	Poisoning	Suffocation	Environmental	Poisoning
	536	394	267	212	166	5,462
	Unintentional	Adverse	Suicide	Unintentional	Unintentional	Undetermined
10	Suffocation	Effects	Suffocation	Environmental	Poisoning	Poisoning
	430	380	227	208	166	3.700

Age Group

Table 2-5. Mechanisms of Fatal Injuries in the U.S., by Age

Centers for Disease Control, National Injury Prevention Center, WISQARS<sup>TM</sup> (Web-based Injury Statistics Query and Reporting System) http://www.cdc.gov/ncipc/wisqars/

collision, the elderly (particularly those 75years or older) suffer a fatality rate greater than that of any other age group (Cook, Knight, Olson, Nechodom, & Dean, 2000; Margolis et al., 2002). Far more commonly than their younger counterparts, senior motorists
experience acute medical illnesses while driving. Such individuals have a crashassociated odds of death or serious injury that is nearly six times that of same-age drivers whose collision was not associated with sudden illness (Lam & Lam, 2005).

In contrast to younger individuals, seniors are more likely to crash during daylight hours, in good weather, and close to home. Older adults are also more prone to collisions involving intersections, traffic sign violations, right-of-way decisions, left turns, and another vehicle. But, compared with younger cohorts, the older adult driver involved in a crash is less likely to have ingested alcohol. Age-related declines in cognitive function, decreased auditory acuity, changes in direct and peripheral vision, impaired coordination, and increased reaction time all contribute to crashes in elderly motorists (Cook et al., 2000; Emergency Nurses Association, 2000; K. Johnson & Johnson, 2001; Pudelek, 2002a, 2002b)

Automobile-versus-pedestrian incidents are the third most common cause of traumatic death in the over-65 population and seniors have the highest pedestrian mortality rate of any age group (Emergency Nurses Association, 2000; Hui et al., 2002; K. Johnson & Johnson, 2001). In addition to slowed ambulation, many elders suffer from thoracic spine vertebral compression fracture-induced kyphosis. This condition results in a stooped posture, making it difficult to raise the head to see oncoming traffic. Increased reaction time, vision and hearing losses, limited neck rotation, medication use, substance abuse, and impaired judgment also contribute to geriatric pedestrian injury (Emergency Nurses Association, 2000; Pudelek, 2002a) Other etiologies of trauma frequently associated with age-related changes, illness, and functional impairment include burns,



Figure 2-3. Causes of Fatal Geriatric Trauma by Age

National Center for Injury Prevention and Control. http://www.cdc.gov/ncipc/wisqars/. Retrieved April 7, 2006, from the World Wide Web.

suicide, and suffocation (National Center for Health Statistics, 2006a) (Figure 2-3).

The relative incidence of various injury mechanisms can fluctuate markedly from location to location. In an urban Pennsylvania trauma center, Richmond and colleagues (2006) reported that 45% of their injured seniors were involved in motor vehicle collisions, significantly outnumbering those admitted for falls (35%), pedestrian-versusmotor vehicle events (15%), and gunshot wounds (5%). Conversely, investigators at a Minnesota trauma center noted that, in their cohort of 601 geriatric trauma patients, falls were the mechanism of injury in almost 60% of cases, motor vehicle crashes accounted for another 36%, and there almost no instances of penetrating trauma (Zietlow et al., 1994). A statewide study of over 77,000 injured elders admitted to Washington hospitals found that unintended falls represented 45% of admissions, motor vehicle-related injuries accounted for 16%, assaults or suicide attempts represented 6%, and the remaining injuries were attributed to diverse or unspecified causes (Mann et al., 2001).

# Aging and Traumatic Injury

Regardless of chronologic age, the process of growing old is highly individual; no two people age at the same rate or in the same way. There are major differences between individuals' physiologic reserves and their disease exposure, severity, and its functional impact. Nevertheless, some aging processes are universal. Over time, the number of normally functioning cells in the body is reduced, oxygen consumption declines, and response to physiologic stressors is blunted, increasing both the risk for trauma and the subsequent morbidity and mortality associated with injury (Resnick, 2005).

# Cardiovascular system changes.

Among the injured elderly, shock represents the primary cause of death (Kuhne, Ruchholtz, Kaiser, & Nast-Kolb, 2005; Novak, 2005). Yet, in patients with a history of hypertension, hypotensive episodes can be difficult to detect. Several normal cardiovascular changes affect how the aging body responds to shock states. Left ventricular wall thickening, myocardial irritability, calcification and fibrosis of the great vessels and heart valves, loss of myocardial compliance, and decreased stroke volume all combine to blunt the body's response to stress (Draude, 2004). Common medications, such as digoxin and beta-blockers, limit compensatory reactions to shock by inhibiting the normal tachycardic response (Atwell, 2002). In addition, many elders are at increased risk for hemorrhage following injury due to liver disease or the routine use of warfarin (Coumadin), aspirin, and other anti-clotting agents (Lavoie et al., 2004; Mina, Bair, Howells, & Bendick, 2003; Reynolds, Dietz, Higgins, & Whitaker, 2003).

As a result of the geriatric patient's dependence on preload, even minor hypovolemia can significantly compromise cardiac function. Hypovolemia worsens diastolic dysfunction, decreases renal and coronary perfusion, and impairs tissue oxygen delivery. This leads to myocardial ischemia and wound-healing failures (K. Johnson & Johnson, 2001). The aging heart is also less sensitive to both endogenous and exogenous catecholamines, which restricts its ability to mount a compensatory response to hypovolemia (Tresch & Poornima, 2000). Each of these age-related changes makes it considerably more difficult for the injured geriatric patient to recover from hypovolemic, distributive, or cardiogenic shock states (Asuncion & Kaushik, 2000)

## Respiratory system changes.

The normal chest wall and lung changes that accompany aging cause a gradual decline in respiratory function. Loss of lung elasticity reduces pulmonary compliance, which leads to small airway collapse, uneven alveolar ventilation, and air trapping (Draude, 2004). Age-associated parenchymal changes limit the alveolar surface area available for gas exchange creating a ventilation-perfusion mismatch that in turn causes a decline in arterial oxygen tension (PaO<sub>2</sub>) (Criddle, 2009; Sue, 2000). With advancing age, the spine and rib cage undergo progressive osteoporotic changes and vertebral collapse, producing kyphosis and making the thoracic skeleton vulnerable to fractures.

Contractures of the intercostal muscles and calcification of the costal cartilage restrict rib mobility and reduced chest wall compliance (Draude, 2004). Progressive loss of strength in the respiratory muscles is accompanied by a decline in maximum inspiratory and expiratory force by as much as 50% (Rosenthal & Kavic, 2004). These changes can severely limit the older adult's ability to increase oxygen demands in the face of injury, particularly thoracic trauma. Albaugh and colleagues examined patients with flail chest (multiple contiguous rib fractures) and determined that the likelihood of death increased by 132% for every 10 years of age, starting in the second decade and continuing through the eighth decade of life (Albaugh et al., 2000).

#### Neurologic system changes.

Age-related physiologic changes to the nervous system are complex and far reaching. Sensory perception declines steadily with normal aging and the incidence of neurological disorders increases with every decade of life (Timiras, 2003). Between the ages of 40 and 70 years, a 10% reduction in brain size occurs as a result of the progressive, scattered loss of approximately 20% of cerebral cortex neurons. This neuronal loss is accelerated by Alzheimer's disease and alcoholism (Timiras, 2003). Loss of brain mass also increases the space available for subdural blood accumulation following head injury. Despite similar injury severity, the mean acute subdural hematoma volume in patients over the age of 65 years is significantly larger than in younger subjects (Howard, Gross, Dacey, & Winn, 1989). As brain weight decreases, cerebral blood flow is concomitantly reduced, placing older adults at increased risk for ischemic insults. Neuronal loss is also associated with slowed impulse conduction through the nerves, which diminishes an elder's ability to deal with multiple stimuli and respond to information in order to prevent injury (Timiras, 2003).

As is true in younger individuals, brain injury is the leading cause of traumatic death in the geriatric population. Over the age of 65, the incidence of traumatic brain injury increases with age and male gender (Coronado, Thomas, Sattin, & Johnson, 2005) and age becomes an important predictor of in-hospital death (Conroy & Kraus, 1988). Gan and associates (2004) noted that brain-injured elders had a mortality that was double that of their under-64-year-old cohort. Howard and colleagues documented a case-fatality rate four times higher in subdural hematoma patients over the age of 65 years (Howard et al., 1989). In their series of patients between the ages of 80 and 100 years, Cagetti and colleagues reported no survivors among elders admitted with a Glasgow Coma Scale score of 11 or less (range 3-15) (Cagetti, Cossu, Pau, Rivano, & Viale, 1992).

Cervical spine fractures in older adults tend to involve more than one level, commonly occurring at C1-C2. These fractures are frequently unstable (Jacobs et al., 2003). The number of spinal and spinal cord injuries in seniors appears to be on the rise as the population ages. A longitudinal Finnish study (1970-1995) examined patients over the age of 50 who had sustained a fall-induced, fracture-associated, spinal cord injury. Researchers found a 24% average annual increase in the incidence of these injuries over the course of the five-year study (Kannus et al., 2000). Spivak and associates reviewed a series of cervical spine injuries and noted that in-hospital mortality for persons over age 65 was 60 times that of their under-40-year-old patients (Spivak, Weiss, Cotler, & Call, 1994).

# Musculoskeletal system changes.

As the body ages, not only is muscle mass diminished, but the remaining myocytes lose functional capacity due to a reduction in myosin adenosine triphosphatase (ATP) (Resnick, 2005). This loss diminishes the muscle's ability to extract and utilize oxygen, which increases fatigue and reduces overall muscle strength (Atwell, 2002). Osteoporosis, a common accompaniment of aging, limits production of new bone cells. The resultant loss of mass is associated with bone fragility, predisposing the older adult to bony fractures following even minor trauma. It is not surprising then, that the incidence of fractures is higher in the geriatric population than in any other age group (Hall & Owings, 2000; Resnick, 2005).

Falls are the leading cause of pelvic fractures in the elderly. In a large, statewide

study, Richmond and colleagues found that extremity or pelvic fractures were the primary (most severe) injury in 44% of their 65-to-74 year-old multi-trauma patients and in 55% of those over 85 years (Richmond et al., 2003). The highest frequency is seen in women older than 85. In one series, 126 of 148 pelvic fracture patients were female (R. Morris, Sonibare, Green, & Masud, 2000). Unlike younger adults, pelvic fractures in the elderly are generally the result of low energy force (same-level falls) and involve only a single break (R. Morris et al., 2000). Following pelvic fracture, older patients suffer mortality rates three-to-five times greater than their under-55-year-old counterparts (Atwell, 2002).

The risk of fall-related hip fractures also increases with advancing years and these injuries are three times more common than pelvic fractures (R. Morris et al., 2000). In fact, 60% of seniors hospitalized for a fracture have a hip fracture (Hall & Owings, 2000). However, evidence suggests that some individuals have hips so osteoporotic that spontaneous fracture actually precedes the fall (Emergency Nurses Association, 2000).

### Integumentary system changes.

Aging is associated with reduced effectiveness of several of the skin's protective functions, increasing the older adult's vulnerability to trauma. Subcutaneous fat is lost, particularly the fatty pads that protect boney prominences. Both the dermis and epidermis thin, making delicate, aging skin susceptible to tears (Novak, 2005). Senescent changes also occur in the structure of interstitial tissues, which predisposes seniors to soft tissue injury (Rosenthal & Kavic, 2004) commonly manifest as bruising. All aspects of wound healing appear to be influenced by aging. Responses in both the inflammatory and proliferative wound healing phases are decreased and angiogenesis, epithelialization, and wound remodeling are all delayed (Criddle, 2009). Fibroblast proliferation and collagen synthesis also diminish with aging, slowing wound healing after injury. Once the body's protective layers are breached, external barriers to bacterial invasion are removed, promoting wound infection. This is aggravated by the immune system alterations that accompany aging, which limit the older adult's ability to mount an adequate response to post-traumatic infection (Atwell, 2002; K. Johnson & Johnson, 2001).

### Comorbidities and the Geriatric Trauma Patient

In addition to the normal changes of aging that increase the morbidity and mortality of trauma, older patients commonly have one or more disease states prior to injury. These are variously referred to in the literature as "chronic medical conditions" (McGwin, MacLennan, Fife, Davis, & Rue, 2004), "preexisting conditions" (Grossman et al., 2002; Jacobs et al., 2003; McGwin et al., 2004), "preexisting morbidity" (Cameron et al., 2005a), "preexisting disease" (MacKenzie, Morris, & Edelstein, 1989), "pre-injury illness" (Sacco et al., 1993) or "comorbidities" (McMahon, Schwab, & Kauder, 1996; Tan, Ng, & Civil, 2004; Wardle, 1999).

A large Canadian study (N = > 21,000) suggests that the frequency of preexisting comorbid conditions in persons admitted for trauma care differs significantly from that of the general population. Compared to non-injured matched controls, trauma patients had higher Charlson Comorbidity Index scores, 1.9 times higher rates of hospital admissions, and 1.7 times more physician claims in the year prior to the injury. Similarly, in the pretrauma year, persons in the injured group had a hospital admission rate for mental health disorders 9.3 times higher, and physician claims for a mental health disorder 3.5 times greater, than did non-injured controls. Regrettably, this review was limited to 18-to-64 year-olds, omitting the geriatric patient population (Cameron et al., 2005a).

Although there have been several published reports of comorbidity and the trauma patient, comparisons between studies are limited by the lack of standard definitions. The prevalence of preexisting conditions, however, may not be as high as assumed. In a large investigation of the prevalence of chronic, pre-injury disease in trauma patients, Hannan and colleagues identified that 63% of their oldest subjects (> 85 years) were free of comorbid conditions and only 13.7% had two or more chronic disorders (Hannan et al., 2004).

Once a patient is injured, researchers have attempted to quantify the impact of preexisting disease on trauma outcomes. In an early cohort study that matched injured survivors (all ages) with trauma patients who died in-hospital, Morris, MacKenzie, and Edelstein reported relative odds that varied between 4.5 (cirrhosis) and 1.2 (diabetes) for 11 preexisting chronic conditions (J. Morris et al., 1990). In a similar study, Grossman's group limited their series to geriatric trauma patients who died in-hospital and found that, after controlling for common variables, the preexisting conditions with the strongest effect on mortality were hepatic disease (OR, 5.1), renal disease (OR, 3.1), cancer (OR, 1.8), and chronic steroid use (OR, 1.6) (Grossman et al., 2002).

A more recent study (McGwin et al., 2004) reported the relationship between age, preexisting chronic medical conditions, and in-hospital mortality. These investigators concluded that, while patients 50-64 years of age who sustained moderate or severe injuries were not at increased risk for death, those over the age of 65, with one or more comorbidities, had relative risks of in-hospital death of 1.13 (moderate injury) and 1.88 (severe injury) compared to equally injured, same-age patients without chronic disease.

This increase in mortality appears to be related not only to preexisting disease, but its relationship to in-hospital complications as well. In their statewide study of geriatric trauma patients, Richmond and colleagues noted that those with one or more preexisting comorbid conditions had three times the likelihood of developing an in-hospital complication than did those without comorbidities (Richmond, Kauder, Strumpf, & Meredith, 2002). Moreover, injury itself appears to become a chronic condition in a significant proportion of elderly patients (Gubler et al., 1996). A study of persons over the age of 70 at the time of injury revealed that older adults who had experienced trauma were 3.25 times more likely than a matched, non-injured cohort to be hospitalized again for injury during the six year follow-up period (McGwin et al., 2001).

#### Trauma Systems

A trauma care system involves a continuous and comprehensive approach to the treatment, transport, and care of traumatically injured patients in order to optimize outcome (Kai-tak et al., 2006). The American College of Surgeons defines a trauma care system as being composed of four basic elements: access to care, pre-hospital care,

trauma hospital care, and rehabilitation (American College of Surgeons, 1999).

Since publication of the 1966 landmark report, *Accidental Death and Disability: The Neglected Disease of Modern Society* (National Research Council), a huge amount of public effort and funds have gone toward the creation of systems designed to provided specialized care to those most seriously injured. In 1976, the American College of Surgeons Committee on Trauma published criteria for trauma hospital categorization and organized trauma systems have since been established in most areas of the country (Zimmer-Gembeck et al., 1995). Several studies have documented reduced in-hospital mortality among the seriously injured when the requisite services, expertise, and resources are concentrated in a defined number of trauma care facilities (Dudley, Johansen, Brand, Rennie, & Milstein, 2000; Mann & Mullins, 1999; Mann, Mullins, MacKenzie, Jurkovich, & Mock, 1999; Nathens et al., 2001; Peleg et al., 2004).

In 1988, West and colleagues established criteria for evaluating trauma systems (West, Williams, Trunkey, & Wolferth, 1988). These criteria include: the authority to formally designate and categorize hospital trauma centers; implementation of the American College of Surgeons trauma guidelines; on-site visits to verify compliance with trauma center standards; an appropriate number of designated facilities for the population served; adequate pre-hospital trauma care guidelines and transfer protocols; a trauma registry; and a means for evaluating trauma system performance. Regions meeting all eight of these criteria were considered "complete" or "mature" trauma systems (Mann, Mackenzie, Teitelbaum, Wright, & Anderson, 2005).

There is substantial variation across states and only a few have developed comprehensive trauma systems designed to systematically capture and direct the management of patients injured anywhere in the state (MacKenzie et al., 2006; Mann et al., 2005; Pfohman & Criddle, 2004). Population-based evidence supports a 15-20% improved survival rate among seriously injured patient treated in coordinated trauma systems (Celso et al., 2006; Mullins & Mann, 1999). Yet, despite a long history of trauma system development, by 2005 only eight states (including Oregon) met all eight of West's criteria and only 25 U.S. states could claim comprehensive, statewide trauma coverage (Mann et al., 2005).

One of the mandates of trauma center verification is the maintenance of a detailed patient registry. These data-rich registries have proven to be invaluable tools for documenting inpatient care and hospital outcomes. Nevertheless, missing from both state and hospital registries is any post-discharge data. Because of this, the current published literature on trauma system effectiveness relies solely on hospital survival as a measure of system success (Mann et al., 1999). While this information deficit affects all trauma patients, the elderly are disproportionally underrepresented by lack of ongoing follow-up.

## Providing Trauma Care to the Geriatric Patient

The elderly represent a significant proportion of the injured population and associated trauma resource utilization. Not only is the incidence of traumatic injuries high in the senior population but, as a result of reduced physiologic reserves and preexisting health conditions, injured geriatric patients require hospitalization for trauma at a rate twice that of the general population. Consequently, the financial impact of caring for the wounded elderly is considerable (J. S. Young, Cephas, & Blow, 1998). At present, resources required to achieve optimal recovery among geriatric trauma patients, particularly treatment in intensive care units, greatly exceeds those required by younger patients with a similar injury profile (Sartorelli et al., 1999; Zietlow et al., 1994). While representing just over 10% of injured inpatients, older individuals consume one-quarter to one-third of all trauma health care resources (Mann et al., 2005; McGwin, Melton, May, & Rue, 2000; McMahon, Shapiro, & Kauder, 2000; Sattin & Mullins, 2002; CW Schwab, MB Shapiro, & DR Kauder, 2000; Taylor et al., 2002; U.S. Dept. of Health & Human Services, 2003; Wright & Schurr, 2001).

In a 1999 study, Sartorelli and colleagues (1999) examined the trauma reimbursement-to-cost ratio in three patient age groups at one Level 1 trauma center. These investigators noted that, for both their pediatric (< 17 years) and mid-age patients (17-64 years), reimbursement exceeded cost of care. Although there was no difference in Injury Severity Scores, this finding was not true for geriatric patients ( $\geq$  64 years). The elderly cohort had a significantly longer length of stay, which drove charges to exceed reimbursements. Taylor et al., (2002) also noted that, once admitted to an intensive care unit, geriatric trauma patients had significantly longer lengths of stay than did younger individuals, associated with markedly increased costs of care. Additionally, older trauma patients require more medical and subspecialty consultation during hospitalization than do younger patients with similar injuries indicating that, for older adults, recovery is often a complicated process (McKevitt et al., 2003; Richmond et al., 2006).

### In-Hospital Mortality Following Geriatric Trauma

In the late 1980s, Champion and colleagues analyzed data from 111 U.S. and Canadian trauma centers and compared outcomes between young and older (≥ 65 years) trauma patient populations (Champion et al., 1989). This sentinal work was the first major study to document the high case fatality experienced by geriatric trauma patients. Because in-hospital death is easy to identify, the incidence of mortality among hospitalized injured seniors has continued to be well studied. Findings, however, vary greatly depending on the location and year, and both the age and injury criteria used. Nonetheless, the elderly appear to experience in-hospital case-fatality rates two to six times greater than younger adults with equivalent injuries (Atwell, 2002; Bergeron et al., 2003; Finelli et al., 1989; Grossman et al., 2002; Gubler et al., 1997; McGwin et al., 2000; McMahon et al., 2000; Perdue et al., 1998; Pereira et al., 2006; C Schwab, M Shapiro, & D Kauder, 2000; C. W. Schwab, M. B. Shapiro, & D. R. Kauder, 2000; Stassen et al., 2001; Susman et al., 2002).

A two-year, prospective outcome study in Maryland—a state with a welldeveloped and comprehensive trauma system—documented a 1.8% incidence of inhospital death among injured patients less than 65 years of age, but a 6.7% mortality among older individuals. Hannan and colleagues examined the New York State Trauma Registry for mortality associated with blunt injuries and found that individuals between the ages of 13 and 39 years had an in-hospital death rate of 5.1%, while mortality for those over the age of 85 jump to 15.8% (Hannan et al., 2004). A Canadian study identified a 4% in-hospital mortality for 20-to-30-year old trauma patients. This number doubled (8%) for those over 65 years (McKevitt et al., 2003).

In a 1998 study, Perdue and colleagues (1998) compared survival-to-discharge rates in patient cohorts less than and greater than 65 years old. Despite similar injury severity scores, mortality was 6% in the younger subset and 14% among seniors. A five-year study of trauma patients admitted to one tertiary intensive care unit identified a 5.3% in-hospital mortality in their younger group and a 16.2% mortality among those age 65 and up (C. Johnson, Margulies, Kearney, Hiatt, & Shabot, 1994). Shiller and colleagues compared survival-to-discharge in trauma patients under and over age 60. Throughout their five-year study period, mortality was 17.1% in the younger group and 31% in those over 60 years (Schiller et al., 1995).

Several other trauma researchers, who documented fatalities only in their elderly patients (no younger comparison group), have reported in-hospital mortality rates of 9.9% (Meldon et al., 2002), 10% (Richmond et al., 2002), 11% (Ferrera, Bartfield, & D'Andrea, 2000), 12% (Hui et al., 2002),15% (Oreskovich et al., 1984; Ross, Timberlake, Rubino, & Kerstein, 1989), 16% (Pickering, Esberger, & Moran, 1999), 18.1% (Tornetta et al., 1999), and 23% (Battistella et al., 1998; Zietlow et al., 1994).

A trend that has been described by several investigators is the high mortality rate beyond the first day in the geriatric multi-trauma patient. Whereas the majority of fatally injured younger adults will die within 24 hours of the initial insult, traumatized seniors continue to experience an ongoing, elevated risk of in-hospital death (Acosta et al., 1998; Demetriades et al., 2004; van der Sluis et al., 1996). In Perdue's sample, 3.9% of patients less than 65 years of age died on post-injury day one; only another 2.3% did not survive to hospital discharge. In contrast, 5.8% of elderly patients died within the first 24 hours, but an additional 8.3% died at some point prior to discharge (Perdue et al., 1998). In their series, Tornetta and colleagues examined only persons over the age of 60. Of a total of 59 in-hospital deaths, 52 patients (88%) survived the first day (Tornetta et al., 1999). Hannan noted that 85% of the in-hospital trauma deaths among patients over the age of 85—and 83% of deaths in those between 74 and 84 years—occurred beyond the first 24 hours post-injury (Hannan, Mendeloff, Farrell, Cayten, & Murphy, 1995).

Single-system injuries, not just multi-system trauma, also appear to significantly affect geriatric patient survival to hospital discharge. Bergeron's group investigated the effect of rib fractures and patient age on mortality and noted that seniors had five times the odds of dying in-hospital when compared to those less than 65 years old (Bergeron et al., 2003). Burns are a particularly devastating form of injury. A three-decade review of 201 consecutive patients over the age of 75, at a single burn center, documented an overall in-patient mortality of 47% (Lionelli, Pickus, Beckum, Decoursey, & Korentager, 2005). Pereira and colleagues (2006) investigated the in-hospital mortality of patients with severe burns (body surface area of 20% or more). They reported the death of less than 15% of victims under the age of 65 years. However, in patients older than 65, mortality was between 42% and 82%. Stassen found that patients over the age of 80 had a 100% mortality with burns of as little as 40% of body surface area (Stassen et al., 2001).

Likewise, severe head injuries are related to high in-patient fatality rates among the elderly. Kilaru and colleagues (Kilaru et al., 1996) retrospectively reviewed the cases of 40 patients older than 65 years who were admitted with a severe head injury (Glasgow Coma Scale score  $\leq$  8). In-hospital mortality for these subjects was 68%. Pennings and associates (1993) compared outcomes in 42 elderly ( $\geq$  60 years) and 50 young adult (20-40 years) patients with brain injuries and an admission Glasgow Coma Scale score of five or less. Despite the fact that there were no differences between the cohorts in various admission severity scores, resuscitation efforts, neurosurgical interventions, or nutritional support, elderly patients had a 79% in-hospital mortality, versus 36% for younger patients. Secondary organ failure was the primary cause of death in 33% of the elderly group, but in none of the younger cohort. Howard et al. limited their series to patients with subdural hematomas. Their 18-40 year-olds experienced an 18% in-hospital mortality but 74% of patients over 65 years of age died before discharge (Howard et al., 1989). A more recent study suggests that survival for the elderly brain-injured population has not improved. Gomez's group examined a patient population similar to Howard's and found an 87% in-hospital mortality (Gomez et al., 2000).

Although downward trends in in-patient deaths are a positive change, they must be viewed in the context of longer-term survival as well. An eight year study (1988-1995) of hospitalization patterns in the state of Washington showed a decline in in-hospital mortality rates while death within 60 days of hospital admission (all ages, all causes) steadily increased over the same time period (Mann et al., 2001). This trend appears to be a function of decreased hospital length of stay. During the study years, the median length of hospitalization declined from just over six days to four days. At the same time, the proportion of geriatric patients discharged to a skilled nursing facility increased (Mann et al., 2001). In an Australian series, O'Hara and colleagues examined 831 deaths that occurred within 28 days of leaving an acute care hospital. Among patients discharged to a long-term care facility, 30% died within in four days of transfer (O'Hara, Hart, Robinson, & McDonald, 1996). Therefore, the current emphasis on early discharge to long-term care, which in many cases simply shifts the site of death, makes hospital mortality rates increasingly meaningless markers of outcome for the injured elderly.

# Inadequacy of Existing Trauma Mortality Models in the Geriatric Population

Current predictive models of trauma deaths still focus on the in-hospital mortality and discharge status of younger individuals while inadequately describing the geriatric patient experience with injury. For decades, the "tri-modal distribution of death" has been the dominant paradigm of trauma mortality (Acosta et al., 1998; Baker, Oppenheimer, Stephens, Lewis, & Trunkey, 1980; Meislin et al., 1997; Peng, Chang, Gilmore, & Bongard, 1998; Trunkey, 1983). This tri-modal model identifies three peak periods of death post-injury. The earliest peak occurs in the first "golden" hour after impact, accounting for approximately 45% of trauma mortality. These deaths are largely attributable to massive head or thoracic injuries. The second peak, responsible for approximately 34% of deaths, occurs within one-to-four hours of trauma, commonly as a result of exsanguination or major neurologic insults. The third mortality peak (20% of deaths) occurs one-to-three weeks following injury and is generally due to organ failure (Trunkey, 1983) (Figure 2-4).

### Figure 2-4. Tri-Modal Model of Trauma Mortality



For many years, this widely accepted model has served as a plausible predictor of mortality patterns in the younger injured patient (Demetriades et al., 2005). However, because it is limited to in-hospital mortality, the tri-modal model incompletely explains the experience of elderly trauma survivors who appear to suffer an ongoing risk of death following hospital discharge. Newer more complete models are necessary to identify actual mortality distribution in the injured elderly. This requires analysis of patient outcomes beyond the period of acute care hospitalization; a number of researchers have begun to address this issue.

# Short-Term Survival (< 1Year) Following Geriatric Trauma

Several investigations have documented the persistent effects of trauma on patients in the weeks following hospital discharge. In an early study of post-discharge outcomes, researchers examined trauma patients of all ages and identified an in-hospital death rate of 21.2 per 100,000 injured patients (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998). This number rose to 35.4 per 100,000, within the first 30 days of discharge indicating that the overall risk of death following trauma remains significant in the immediate post-hospitalization period. In almost all age categories, the death rates for discharged injured patients exceeded the rate expected for equivalent-aged individuals in the general population.

A large-scale Canadian investigation reported 60-day survival in a group of over 18,000 trauma patients (Cameron et al., 2005b). This study examined only 18-to-64 yearolds and included those who died in-hospital. Controlling for demographic factors and preexisting conditions, the adjusted all-cause mortality rate ratio for the first 60 days post injury was 7.29 (95% CI, 4.53-11.74).

Mann and colleagues (2001) investigated 60-day post-injury survival in hospitalized trauma patients. These researchers identified several covariates significantly associated with decreased survival in persons over the age of 65 years. Factors associated with an increased relative risk (RR) of death in the older subset included increasing age (RR, 1.04; 95% CI, 1.02-1.05), male gender (RR, 1.66; 95% CI, 1.50-1.75), head injury (RR, 1.04; 95% CI, 1.59-1.75), increasing ISS (RR, 1.07; 95% CI, 1.07-1.08), and the presence of multiple preexisting conditions. Patients with four or more comorbidities were 4.3 times more likely to die within 60 days of injury.

Irwin's group (Irwin et al., 2004) also performed a 60-day post-discharge followup of over 10,000 trauma patients hospitalized for spinal fractures or spinal cord injuries. Subjects were divided into young (16-64 years) and old ( $\geq$  65 years) cohorts. In-hospital mortality in the young group was 1.4% and there was no significant post-discharge mortality. Geriatric patients, however, not only experienced a 3.5% in-hospital death rate, but total mortality rose to nearly 10% in the first 60 days post-hospitalization.

Richmond and colleagues (Richmond et al., 2006) examined 90-day outcomes in injured patients over the age of 55 years who were discharged from a single Level 1 trauma center. Because these researchers were interested in mental status, depression, and social support post-injury, subjects were limited to individuals who had sufficient cognitive capacity to provide informed consent and participate in interviews. Nevertheless, even among this healthiest of geriatric trauma patient subsets, 90-day mortality was 10%.

An early retrospective review of trauma patients over the age of 65 years (all causes and injuries) found that 17% had died within a six-month follow-up period (Broos, D'Hoore, Vanderschot, Rommens, & Stappaerts, 1993). A British study examined the outcome in a subset of 71 geriatric patients ( $\geq$  70 years) with severe traumatic brain injuries. Each of these patients had a Glasgow Coma Scale score of less than 8 on initial presentation. By the end of the six-month study period, 80% were dead (including those who died in-hospital) and none of the remaining 20% had made a good recovery (Ushewokunze et al., 2004).

Although limited, such evidence suggests that the current trauma center emphasis on hospital survival as the marker of both patient and trauma system success, does not capture the ongoing impact of trauma. In particular, in-hospital death rates substantially underestimate the actual mortality associated with injury in the elderly. After noting that, in their elderly cohort (65-85<sup>+</sup> years), the risk of death within one year was 1.45 to 3.85 times greater than expected norms, Mullins and colleagues posited a quadra-modal model of geriatric trauma mortality (Figure 2-5). This model suggests that the impact of trauma on survival does not end with hospital discharge but persists throughout the first post-injury year (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998). Still, this suggestion is limited by the data available. Are the negative consequences of traumatic injury, particularly in the elderly, limited to one year?



Figure 2-5. Quadra-Modal Model of Trauma Mortality

Historically, the difficulty with capturing these data is that, once a patient is discharged from the hospital, cause of death is rarely recorded as traumatic injury. Mortality is generally attributed to organ failure, pneumonia, exacerbation of a preexisting condition, complications of immobility, cognitive impairment, or diverse infections. Even among persons (all ages) who died within 30 days of hospital discharge following major trauma, one study found that 43% of death certificates recorded a noninjury reason for patients' demise (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998).

# Intermediate-Term Survival (1-4 Years) Following Geriatric Trauma

A few researchers have investigated intermediate-term (1-to-4 years) survival in the injured geriatric population. A 2003 investigation examined trauma patient outcomes one year after injury. Of the 4,136 patients discharged alive (all ages), only 91 (2%) were dead at one year, indicating a low overall incidence of post-hospitalization death. But, when the subset of elders was analyzed separately, persons over the age of 65 years had 15 times the post-discharge mortality of younger individuals in this sample (Olson, Brand, Mullins, Harrahill, & Trunkey, 2003).

Gallegher and colleagues (2003) noted a 36% incidence of death within two years of major trauma in patients older than 60 years. In a Dutch study of major trauma patients (ISS  $\geq$  16), van der Sluis reported a two-year mortality of 9.5% in persons over the age of 60 (van der Sluis et al., 1996). A four-year (minimum) follow-up study by Battistella and associates identified a 47% mortality in elders who were 75 years or older at the time of injury (Battistella et al., 1998). And, Morris and colleagues tracked survival following isolated pelvic fracture in a geriatric population with a mean age of 83. The one-year mortality in this very old group with a single-system injury was 27% (R. Morris et al., 2000).

Importantly, none of these investigators compared mortality in their geriatric

populations to predicted mortality for non-injured, matched controls. This makes interpreting their findings difficult because of the inherently high incidence of death among the elderly. In particular, persons who have been recently hospitalized may have an elevated risk of death. In a follow-up study of 646 randomly-selected Veterans Administration patients, Liu and Sullivan (2003) found an all-cause mortality of 13% within 12 months among patients who had been hospitalized for any reason.

## Long-Term Survival ( $\geq$ 5 Years) Following Geriatric Trauma

Very few researchers have looked at the impact of trauma on survival over the course of five or more years. In the largest population-based study to date, Cameron and colleagues (Cameron et al., 2005b) followed non-geriatric trauma patients (ages 18-64) for a decade post-injury and matched them with demographically similar controls. Including patients who died during the index hospitalization, they identified an overall adjusted mortality rate ratio of 1.70 (95% CI, 1.54-1.87) that remained persistently higher than controls throughout the 10-year period from the date of injury. The total number of deaths among subjects that were attributed to their injury was 41%, accounting for 536 of the 1,306 fatalities over the course of 10 years. These investigators noted that the incidence of death in injured subjects doubled exponentially in each age group beyond 34 years. The youngest cohort (18-24 years) had a mortality rate of 33 per 10,000 but this number climbed to 256 per 10,000 in the 55-to-64-year-old group. No geriatric patients were included in this analysis.

Gubler and colleagues (1997) published the first major study to quantify the effect

of injury on lifespan in the elderly, compared to matched controls. Older trauma survivors ( $\geq$  66 years) from around the country were tracked for five years after hospital discharge. Using Medicare records, these patients were matched with uninjured individuals for age, sex, and preexisting conditions. Researchers found that the relative risk of death over a five-year period in those who had suffered major trauma was 71% higher than in persons who were uninjured. Similarly, using data from the Longitudinal Study on Aging, McGwin, Melton, May, and Rue (2000) followed discharged geriatric trauma patients ( $\geq$  70 years) for a six-year period subsequent to injury. They observed a hazard ratio for mortality of 1.5 compared to an uninjured cohort, matched for age and gender, identified in the Longitudinal Study of Aging. These reports suggest a quintamodal distribution of trauma death in older persons due to the long-term relationship between injury and lifespan.

### Functional Outcome Following Geriatric Trauma

In the elderly population, even minor trauma may result in a substantial loss of pre-injury abilities (Novak, 2005). An early study (1984) of functional outcome following geriatric injury found that only 8% of survivors ( $\geq$  70 years old) had returned to independent living one year following major trauma (Oreskovich et al., 1984). Recent reports offer a considerably more favorable post-injury picture. Fifty seven percent of DeMaria's patients over the age of 65 were able to return to independent living after their injuries (DeMaria et al., 1987). In 1994, a decade after Oreskovich's dismal study, Zietlow and colleagues noted that 68% of their elderly patients ( $\geq$  65 years), who

survived to hospital discharge, were living at home with an independent functional status 12 months after injury. Among the subgroup of injured seniors without significant neurologic insults, fully 85% were returned home and eventually resumed independent function (Jacobs, 2003; Zietlow et al., 1994). Similarly, a 2003 study found that 75% of geriatric ( $\geq$  65 years) trauma survivors were living independently two years after discharge (McKevitt et al., 2003).

Grossman compared functional outcomes in octogenarians with blunt trauma to an equivalently-injured group of younger geriatric patients (65-to-79 years old). Not surprisingly, functional outcome was worse in the older group. Octogenarians experienced more locomotion and transfer limitations but independence in feeding and social interaction were generally preserved in those with minor or moderate injuries (Grossman et al., 2003). Not all authors, however, have been able to document such optimistic results. Functional recovery in the subset of elderly trauma patients with severe trauma, major brain injury, or extensive burns is notoriously poor, with disability rates more than double those of younger patients (Lionelli et al., 2005; Pennings et al., 1993; Pereira et al., 2006; Susman et al., 2002).

#### Review of the Proposed Study Site, Data Sources, and Measures

The following section reviews the site, data sources, and measures selected for the proposed study.

# The Oregon Trauma System

Oregon will serve as the site for the proposed study. The state has long been recognized throughout the nation as a leader in trauma system development. Established by public statute in 1985, the Oregon Trauma System has been functioning since 1987. Although it was the second state in the nation to develop a comprehensive, statewide trauma program, Oregon was the first to construct a system that incorporated small rural hospitals as well as large urban facilities (Kai-tak et al., 2006). Nationwide reviews in both 1993 and 1999 (Bass, Gainer, & Carlini, 1999) found that Oregon was one of just five fully operational statewide trauma systems in the U.S.. Even as recently as 2005, Oregon was still one of only eight states to meet all of the West criteria (West et al., 1988) to qualify as a "mature" trauma system (Mann et al., 2005).

The Oregon Trauma System is regulated by the Oregon Health Division. In 1987, implementation of the trauma system began in the Portland metropolitan area, where the state's only Level I trauma centers are located. Over the next five years, the remaining areas of this largely rural state were integrated into the trauma care system. As initially conceived by the American College of Surgeons, trauma systems would have three levels of care. Participating facilities would be designated Level I (highest), II, or III by meeting specific criteria. Oregon, however, wanted to build a comprehensive system that would encompass the entire state, including small hospitals in tiny rural communities.

With this in mind, Oregon developed criteria for Level IV trauma hospitals so that even remote and rural regions of the state would be included in the system. Level III and IV hospitals function primarily as stabilization centers that initiate care and facilitate timely transfer to Level I or II institutions. This inclusive system provides small centers with funds for equipment and education, requires each facility to follow specific patient care and triage protocols, and mandates participation in the Oregon Trauma Registry (Mann et al., 2001) Although numbers have fluctuated over the years, there are now 50 hospitals participating in the Oregon Trauma System, including four in Southern Washington, one in Idaho, and one in Northern California. Currently, Oregon has two Level I, five Level II, 19 Level III, and 24 Level IV designated trauma care facilities (Appendix A).

Improved survival following establishment of the Oregon Trauma System has been documented by Mullins and colleagues (1998) who compared trauma patient outcomes with adjacent Washington state, both before and after the establishment of Oregon's trauma system. Following implementation of the statewide system, these researchers noted a significant reduction in the risk of death among severely injured patients (ISS > 15) in Oregon, compared to similar patients in Washington (adjusted OR, 0.80; 95% CI, 0.70-0.91) (Mullins, Mann, Hedges, Worrall, & Jurkovich, 1998).

Because it is a mature, statewide, inclusive system—with documented improvement in patient outcomes following trauma system initiation—Oregon is well suited as the data source for this project. The goal of this study was to quantify the impact of injury on five-year survival in geriatric trauma survivors. Therefore, selecting a study site with a demonstrated track record for quality patient care was expected to minimize the potential confounding influences of suboptimal pre-hospital or in-hospital care on geriatric patient long-term survival.

# The Oregon Trauma Registry

Although 37 states currently maintain statewide trauma registries, only 15 registries—including Oregon's—are comprehensive, capturing data from small rural hospitals as well as large urban facilities (U.S. Dept. of Health & Human Services, 2002). With data collection ongoing on since 1992, the Oregon Trauma Registry is one of the country's oldest statewide databases, making it well suited for studies of long-term patient outcomes. The Oregon Trauma Registry is a high quality database compiled from standardized reports submitted electronically by all trauma care facilities throughout the Oregon Trauma System. Designated hospitals are required to report specific data to the registry within 90 days of the death or discharge of any patient who meets trauma system criteria (Kai-tak et al., 2006). See Appendix B for a copy of the Oregon Trauma Registry data collection instrument.

The registry is maintained by the Oregon Department of Human Services and is financed by the State's general fund. The Oregon Trauma Registry contains information about the cause of injury, emergency response, hospital course, and discharge status of all patients who meet the following inclusion criteria:

- 1. Patients entered into the trauma system by field personnel.
- 2. Any patient for whom the trauma team is activated at the receiving hospital.
- 3. Any patient whose injuries required a surgeon's evaluation and treatment.
- 4. Any patient transferred to a trauma center for trauma system care.
- 5. Patients who met triage criteria or inter-hospital transfer guidelines at the transferring facility.

Also included are patients who did not receive a trauma team response but retrospectively, at either the transferring or receiving facility, have any of the following:

- 1. An Injury Severity Score greater than 8
- 2. Death
- 3. A major operative procedure to the head, chest, or abdomen within 6 hours of hospital arrival
- 4. Admission to an Intensive Care Unit within 24 hours of arrival.

For the study time period (1992-2000), the Oregon Trauma Registry contains the records of over 50,700 individual trauma patients including 4,162 unique individuals who were at least 65 years of age at the time of injury, and were discharged alive. Figure 2-6 shows the age distribution of Oregon trauma patients by discharge status: dead or alive.



Figure 2-6. Oregon Trauma Registry Patients by Age and Discharge Status

Oregon Trauma Registry, 1992-2000

Figure 2-7 illustrates mortality trends for the same period. From the second through the fourth decades of life, injured Oregonians experience a 95% survival rate following trauma. However, survival dips sharply at the age of 60 years, and again at age 70. By 75 years, survival to hospital discharge for elderly Oregonians drops to only 80% (Oregon Department of Human Services, 2004).



Figure 2-7. In-Hospital Mortality and Patient Age

Oregon Trauma Registry, 1992-2000

# The National Death Index

Patient mortality was ascertained by using the National Death Index (NDI). This database is maintained by the Centers for Disease Control and Prevention's National Center for Health Statistics. The NDI database is a centralized, computerized index of death records from every county in the United States. Data in the NDI are available solely to health researchers for statistical purposes, and are not available to organizations or the general public for legal, administrative, or genealogic use (National Center for Health Statistics, 2004). Information is compiled from computer files submitted by State vital statistics offices. Beginning with deaths in 1979, each record contains a standard set of identifying information.

The NDI employs a complex and highly accurate algorithm to probabilistically match death records with identifiers from other databases. Because reporting to the National Death Index is mandatory for each U.S. county and state, persons not found in the NDI are presumed to be alive. Records are added annually, approximately 14 months after the end of each calendar year. Therefore, subjects missing from this database five years from the time of injury can, with a large degree of confidence, be presumed to be alive.

NDI records also catalog the primary cause of death as recorded on the death certificate (National Center for Health Statistics, 2004). The NDI has a demonstrated ability to match data to death records with multiple identifiers and it is the instrument most widely used by trauma researchers for ascertainment of death following hospital discharge (Grabbe, Demi, Camann, & Potter, 1997; McGwin et al., 2000; Mullins, Mann, Hedges, Worrall, Helfand et al., 1998; Olson et al., 2001; Olson et al., 2003; Rozental et al., 2002; Wolinsky et al., 1997).

# Life Expectancy

This study sought to identify whether injured elders, discharged alive from a trauma center hospital, returned to the same mortality risk predicted for the general population based on age, race, and gender norms. No attempt was made to identify whether patients were already at risk for early death prior their traumatic event. Therefore, only population-based life expectancy data can provide the appropriate control group.

Several approaches to calculating life expectancy have been used in survival studies but each depends on the selection of an appropriate control group. McGwin and colleagues compared their elderly trauma patients with uninjured individuals in the Longitudinal Study of Aging database, matched for age and sex (McGwin et al., 2000). Gubler's group also identified a Medicare control group but matched patients for preexisting conditions as well (Gubler et al., 1997). Other researchers have used wellestablished populations, such as Framingham Heart Study subjects, as controls to perform similar mortality comparisons in non-trauma patients (Peeters et al., 2003).

When matched controls are not readily available, researchers in the United States commonly rely on the U.S. Life Tables to derive a referent group in order to make population-based comparisons. Life tables attempt to answer the question, "how long is a given individual expected to live?" (Blackwell & Pagano, 1996a). In their study of mortality in elderly radial fracture patients, Rozental's group (2002) employed U.S. Life Tables to determine life expectancy, matched for age and gender. Similarly, Mullins and colleagues used U.S. Life Tables to determine the life expectancy of trauma patients, matched for age and gender, compared with the general U.S. population (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998; Rozental et al., 2002).

The United States Life Tables are complied and updated annually from mortality statistics, Medicare data, and population estimates based on the most recent decennial census (Arias, 2004). Under the auspices of the U.S. Department of Health and Human Services, the National Center for Health Statistics produces the U.S. life tables as part of the National Vital Statistics System. In addition to age and gender, these tables include life expectancy information according to race. For persons under the age of 85, life expectancy is calculated from vital statistics and census data. For those between 85 and 100 years, Medicare records are used to establish life expectancy (Anderson, 2000). This yearly report of age-specific death rates is an official Federal document. The U.S. Life Tables are considered legal evidence and are employed by lawyers, insurance analysts, actuaries, pension planners, demographers, and researchers (National Center for Health Statistics, 2006b).

Although helpful for summarizing the current health status of a population, there are limitations to using life tables. Life expectancy is heavily dependent on the criteria used to select the group. For example, in countries with high infant mortality rates, the life expectancy at birth is highly sensitive to the rate of death in the first few years of life. Because age-adjusted calculations are used, the U.S. life tables eliminate this bias. Another important limitation to all life tables is that no allowance is made for expected future changes in life expectancy. Life tables assume that current death rates will be frozen. In general, the effects of these assumptions are minimal over short time spans and toward the end of life (as in the present study), but may be very significant over decades or a generation.

Five-year survival was selected as the variable of interest for several reasons. Theoretically, each injured patient could be tracked until death, and age at death compared to life expectancy. However, a person who is 65 years old at the time of injury might conceivably live another 30 or more years; no trauma database contains information that spans this length of time. Even if these data were available, it would be difficult to separate effects of normal aging, associated comorbidities, and subsequent injuries from the residual effects of trauma in such a distant past. Additionally, trauma care practices have improved dramatically over time. Thus, outcomes from interventions performed 15 or 20 years ago are not likely to provide important data for the treatment of today's injured elders. For these reasons, five-year vital status was chosen as the study endpoint. A similar timeframe has been used to investigate geriatric trauma patient survival in three previous studies (Battistella et al., 1998; Gubler et al., 1997; McGwin et al., 2000).

## Survival Analysis

Logistic regression models are widely used to compare the observed frequency of an event in a group with the expected mortality predicted from modeling the outcome in a normative population (Demetriades et al., 2004; Mullins, Mann, Hedges, Worrall, Helfand et al., 1998; Rzepka et al., 2001; Taylor et al., 2002). Survival models provide an alternative to logistic regression, and are particularly useful when death is the outcome of
interest. Survival analysis is a statistical procedure used to calculate the time elapsed between a given starting point and a specified event (Blackwell & Pagano, 1996b). The initial point of interest in the present study was discharge from the hospital following traumatic injury and the "event" of interest was death. The time variable was years from discharge until death. Through a process referred to as "censoring", survival analysis is able to account for both persons lost to follow up and those in whom the event has not yet occurred by the end of the observation period (Kleinbaum, 1996).

Survival analysis techniques have been used by several researchers to identify excess death in trauma patient populations. In a study of geriatric trauma patient outcomes, Gubler (1997) used survival analysis (Cox proportional hazards model) to demonstrate a reduction in trauma patient survival compared to non-injured, hospitalized controls. Mann and associates employed the same technique to identify the 60-day postdischarge survival of injured geriatric patients before and after implementation of a statewide trauma system (Mann et al., 2001). Cameron's group conducted survival analysis—using the Kaplan-Meier method and Cox proportional hazards model—to identify excess 10-year mortality in former trauma patients, compared to a populationbased sample of uninjured adults (Cameron et al., 2005b).

### Study Site, Data Sources, and Measures Limitations

This study is presumed to be the first large scale research project to evaluate the impact of injury on five-year survival in geriatric trauma patients, with a wide range of injury types and severity, throughout an entire trauma system. However, because data are

from a single, largely rural, predominately Caucasian state in the Pacific Northwest with a well-developed trauma system—results may not be fully generalizable to other geographic regions.

Another limitation of this project is its retrospective design. Initial subject data were obtained exclusively from a single, extensive, electronic database maintained by the Oregon Department of Human Services. This database includes all qualifying trauma patients entered into the Oregon Trauma System for the specified years. Nonetheless, all information was secondary data and was therefore subject to input errors and omissions. The Oregon Trauma Registry's electronic reporting form is standardized, but information is entered by multiple registrars throughout the state, usually one per trauma facility. Professionals from the Oregon Department of Human Services provide new registrars with training and an extensive manual, and they perform periodic spot checks; however, accuracy and consistency cannot be entirely controlled. Additionally, patients who were inappropriately transported to a non-trauma facility, and were not subsequently transferred to a trauma center, are not captured in the Oregon Trauma Registry. There is currently no way to estimate the number of missed trauma cases and no way of knowing whether geriatric patients are over represented in this group.

The most important technical limitation associated with using U.S. Life Tables to calculate life expectancy is that, for the early portion of this study period (1992-1996), information is limited. Ages are only listed in five year intervals (e.g., 70-75 years) and all data for persons over the age of 85 is combined into a single "85 and up" category. Starting with reporting year 1997, U.S. Life Table life expectancy data were divided into

one-year intervals and the oldest category was raised to "100+".

Perhaps the most important conceptual limitation of life tables is that they reflect only aggregate data—mathematical averages—and do not account for important personal variations (Arias, 2004). This makes them valuable for population studies, but nonspecific for application to individuals. Life table accuracy is increased when populations are divided into more homogenous groups based on personal or demographic characteristics. The U.S. Life Tables divide populations only by age, gender, and race (white, African-American/black).

The primary limitation of the National Death Index is that, despite its high match rate, the NDI will fail to ascertain deaths that occur outside of the United States, unreported deaths, and those in which the body's identity is never determined. Additionally, if insufficient identifying data were obtained at the time of the index hospitalization, the NDI will fail to match trauma patients to death certificates. Fortunately, if for no other reason than financial, hospitals are incented to obtain as much patient information as possible.

The Injury Severity Score is the most widely used anatomic scoring system, but it is not without limitations and criticisms. Weaknesses include: 1) any error in body region scoring will affect the total ISS; 2) many different injury patterns can yield the same ISS; 3) injuries to different body regions are not weighted; 4) only one injury per body region can be scored; 5) patients' age is not taken into account; 6) there is no adjustment for preexisting disease, and 7) the ISS may be unable to differentiate between severe injury and poor care (Rutledge, 1996). Nevertheless, the ISS has been shown to correlate linearly with hospital length of stay, morbidity, mortality, and other measures of injury severity (Stevenson, Segui-Gomez, Lescohier, Di Scala, & McDonald-Smith, 2001) In relation to the present study, it is important to note that although the ISS has been shown to be an excellent predictor of in-hospital mortality, there is little data to support its predictive value for long-term disability (Frutiger, 1997; Rutledge, 1996; Tay, Sloan, Zun, & Zaret, 2004).

### Theoretical Framework

As described in the Review of the Literature section, the "tri-modal distribution of death" has been the dominant paradigm of trauma mortality for several decades (Acosta et al., 1998; Baker et al., 1980; Meislin et al., 1997; Peng et al., 1998; Trunkey, 1983). This theoretical framework identifies three peak periods of death post-injury. The first mortality peak is in the "golden hour" after impact, the second happens within one-to-four hours of trauma, and the third mortality peak occurs one-to-three weeks following injury (Trunkey, 1983). For many years, this widely accepted theoretical framework has served as a plausible predictor of mortality patterns in injured patients (Demetriades et al., 2005). However, the tri-modal model was developed in an era when the majority of injured patients were adolescents and young adults, organized trauma care was in its infancy, and documentation of trauma-related deaths ended with hospital discharge.

More recently, researchers have suggested that the traditional tri-modal model incompletely explains the experience of trauma survivors who appear to suffer increased mortality for some time post hospital discharge. Because of the ongoing risk of death noted when patients in their study were tracked for one year after injury, Mullins and colleagues posited a quadra-modal model of trauma mortality (in patients of all ages) that does not end with hospital discharge but incorporates all deaths up to 12 months beyond the initial event (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998; Olson et al., 2003). But, does the impact of traumatic injury on geriatric mortality cease at one year or are detrimental effects ongoing?

### A Quinta-Modal Model of Traumatic Death in Geriatric Patients

To date, limited studies of intermediate-term (1-4 years) and long-term ( $\geq$  5 years) outcomes suggest elderly trauma survivors remain at risk for increased mortality for years after the index event. Therefore, newer, more complete models are necessary to identify actual mortality distributions among injured seniors. This requires tracking patient survival well beyond the period of acute care hospitalization. A few researchers have suggested a model of geriatric trauma mortality that incorporates the impact of injury on lifespan. The goal of the present study was to investigate a hypothesized quinta-modal model of geriatric trauma deaths (Figure 2-8).

Clearly, the elderly represent a significant proportion of the injured population and associated trauma resource utilization, but current predictive models still focus on short-term outcomes in younger individuals and inadequately describe the geriatric patient's experience with injury. In older Americans, widely reported in-hospital mortality statistics are poor markers of trauma patient outcomes and trauma system effectiveness because these numbers have been shown to significantly underestimate the long-term association between injury and reduced lifespan.



Figure 2-8. Theoretical Model: The Quinta-Modal Distribution of Geriatric Trauma Mortality

## Summary

A number of investigations have documented elevated risks of in-hospital mortality in a variety of injured geriatric populations. Looking at specific injury types or severities, several studies have shown that this mortality risk persists in the early (< 1 year) post-discharge period. A few studies have identified that mortality among older patients continues to be elevated for one-to-four years following both major and minor trauma. Many researchers have simply described mortality rates in their particular sample, without reference to expected mortality; an important limitation in studies

involving elders. Only two published investigations have followed older trauma survivors for more than five years and compared survival to a reference group. Both found a significant, ongoing correlation between geriatric injury and shortened lifespan. However, each of these investigations relied on pooled data from across the country. To date, no large-scale study has been published examining the long-term impact of trauma on older adults—across the spectrum of injury types and severity—in a well-established and well-coordinated trauma care system, compared to population-based life expectancy norms.

This study's unique contribution was to address the following gaps in the literature:

1. A comprehensive, statewide, trauma perspective. As one of only a few states with a mature and comprehensive trauma system, Oregon offers an unparalleled opportunity to look longitudinally at the influence of trauma on long-term geriatric survival—across the spectrum of injury types and injury severity—in a state with a well-established and well-coordinated system of care. This removes many of the biases encountered by earlier investigators whose studies either involved only one trauma center, multiple trauma systems, or only short-term outcomes.

2. Identification of factors associated with survival following hospital discharge. Investigators have previously described variables related to in-hospital geriatric trauma patient mortality. The present study identified key patient and injury variables—present at the time of hospital discharge and currently documented in the trauma registry—that predicted five-year survival following discharge.

These findings will provide a baseline that can be used for future comparisons between patients, interventions, and settings.

### Chapter 3—Research Design and Methods

# Methodology

Aims

The research question of this study was: does traumatic injury influence time to death in elderly patients who survive to trauma center discharge? If so, what key patient and injury variables predict five-year post-discharge survival? These questions were addressed in two specific aims:

1) Quantify the impact of injury on the five-year survival of discharged elderly patients in the Oregon Trauma Registry compared to a hypothetical, age, race, and gender matched, referent group (Figure 3-1).

2) Identify patient and injury variables, present in the Oregon Trauma Registry, that predict five-year vital status in elderly trauma survivors (Figure 3-2).

Approval for this study was granted by the institutional review boards of the Oregon Health & Science University (Appendix C), the Public Health Division of the Oregon Department of Human Services (Appendix D), and the National Center for Health Statistics (NCHS) (Appendix E).

Figure 3-1. Aim 1 Population, Variables, and Methods



Figure 3-2. Aim 2 Population, Variables, and Methods



## Sample

This retrospective cohort design study examined all individuals entered into the Oregon Trauma Registry (OTR) who met the following inclusion criteria, regardless of mechanism of injury or Injury Severity Score (ISS). Subjects were:

- 1. at least 65 years of age at the time of injury;
- 2. injured between 1992 (trauma registry inception) and 2000 (to allow five years to elapse from the time of injury); and
- 3. discharged alive from a trauma center following the index hospitalization.

Patient records for this study (N = 4,572) were obtained from the Oregon Trauma Program, a division of the Oregon Department of Emergency Medical Services and Trauma Systems. Records were received electronically, in a CD-ROM text file, and converted to an Excel spreadsheet (Microsoft Excel for Window, 2003). A unique number was assigned to each record (Figure 3-3). Because some patients had several records for the same injury event, and others had more than one traumatic event during the study period, an index hospitalization record was identified and a unique number was assigned to each subject (n = 4,162). Three hundred and sixty seven patients had multiple records for a given injury event (indicating interfacility transfers) and there were 27 trauma recidivists who appeared in the database with a second or even a third (n = 1) injury. By identifying index hospitalizations, each unique individual only appeared once in the final data set.

The index hospitalization record was defined as the final (discharging) trauma center's record for the patient's first qualifying injury event during the study years. This



## Figure 3-3. Subject Sample and NDI Matching Process

OTR = Oregon Trauma Registry, NDI = National Death Index, SSN = Social Security

record was selected because it contained the most complete documentation of subjects' demographic information, as well as pre-hospital and in-hospital care. Index hospitalization records also contained patients' final diagnoses, Injury Severity Scores, and discharge information.

Data from other records associated with the same injury event were merged with the index hospitalization record only when it served to more fully describe the cause of injury. For example, if a patient was transferred to and treated at three trauma centers, the index hospitalization record might describe cause of injury as "fall", while the initial receiving facility's report described the mechanism as a "six foot fall", and the second facility documented the event as "fall from a running horse". In such instances, information was combined to read "six foot fall from a running horse". In another case, the discharging trauma center referred to the patient's mechanism of injury as "auto versus pedestrian at 5 mph". However, the initial facility's description contributed the information that the patient was "hit by Ford Expedition and dragged under vehicle". These accounts were combined to: "hit by Ford Expedition at 5 mph; dragged under vehicle." Approximately 200 index hospitalization records were modified in this manner.

Records with no discharge data (n = 445) were considered too incomplete to meet the goals of this study and were removed. Also eliminated were 34 records that documented a discharge date that occurred prior to the date of injury; these records were assumed to be erroneous.

Because the focus of this study was outcomes in patients who survived to trauma center discharge, a further group was eliminated. This subset involved patients whose

reported survival on the recorded date of hospital discharge was considered suspect. For example, the list of patients discharged alive included an 81-year-old pedestrian, struck by a car, who sustained a pelvic fracture, basilar skull fractures, and deep coma. He had an Injury Severity Score of 35, indicating severe trauma. The OTR documents that this individual was discharged home three days after sustaining these injuries.

Examination of such cases suggested that the patient probably died in-hospital, and was mis-coded as Discharged Alive. Therefore, the records of all subjects whose time to death was less than or equal to 0.02 years (approximately one week) were individually reviewed to identify those with injuries severe enough that trauma center discharge within one week of the inciting event would seem unlikely. Information from this group of 15 subjects (with patient identifiers removed) was sent to three clinical experts who were asked to decide whether or not, in their opinion, the patients in question could have reasonably been expected to be well enough to no longer require trauma center care within the documented timeframe. The expert panel consisted of three masters or doctorally prepared clinical nurse specialists, experienced in the care of trauma patients. When expert consensus concluded that the data provided were suspect, subjects were eliminated from the study (n = 15).

### Death Ascertainment

In order to identify death date and determine five-year vital status, the names, genders, birth dates, and social security numbers from all 4,572 records initially received from the OTR were submitted to the National Center for Health Statistics (NCHS). Using

their probabilistic matching algorithms, the NCHS crossmatched these patient identifiers with the National Death Index (NDI). A text file containing possible matches was delivered on a CD-ROM and converted to an Excel spreadsheet. For a sample NDI Retrieval Report, see Appendix F.

The NDI crossmatch produced a total of 21,741 probabilistic matches. Patients with common names—such as Johnson, Baker, or Jones— returned up to 50 matches each (the NDI maximum). Any NDI record in which the death date preceded the date of injury or occurred prior the study period (1992-200) was considered a non-match, and was eliminated.

All potential matches were reviewed, rated, and categorized into one of seven levels, based on the quality of the match:

- 0 No NDI match returned.
- 1 Exact social security number (SSN), name, and birth date matched.
- 2 SSN match was exact, but birth date was off by one field.
- 3 SSN was off slightly (e.g., one number was incorrect, or two consecutive numbers were incorrect) but name and birth date matched.
- 4 SSN matched exactly, but name and birth date were more than slightly off (e.g., birth date was off by more than one field, first name did not match).
- 5 No SSN was available for this subject, but name and birth date matched.
- 6 Either SSN or birth date were off considerably (e.g., three or more fields did not match), or both were off slightly (e.g., one number was incorrect, or two consecutive numbers were incorrect).

7 No close match could be made for this subject.

An exact NDI match (level 1, evidence of death) was established for 2,422 subjects; no match was returned (level 0, no evidence of death) for 1,506. For the remaining 644, only partial matches (levels 2-7) were retrieved. After eliminating inadequate OTR records (duplicate entries, those missing discharge data, and patents with impossible death dates), each of the subjects for whom vital status was uncertain (match levels 2-7) was individually entered into the Social Security Death Index (SSDI).

Using the Rootsweb interface (http://ssdi.rootsweb.ancestry.com), the SSDI database was searched by name, birth date, and social security number to identify potential matches. Data are entered into the SSDI approximately six months after death; therefore information is more current than that obtained from the NDI. Additionally, because of its ability to search for subjects based on a variety of criteria, the SSDI provided the flexibility required to attempt various search combinations. For a sample SSDI search, see Appendix G.

Based on the results of the SSDI search, all subjects initially in match levels 2-7 were reclassified to level 0 (no evidence of death, presumed alive), level 1 (evidence of death, presumed dead), or level 7 (ambiguous vital status). Using this search methodology, 35 patients (< 1%) could not be clearly determined to be alive or dead; these match level 7 subjects were eliminated from the study. Only individuals with a match level of 0 (no evidence of death) or 1 (evidence of death) were retained in the final sample. Altogether, of the 4,162 index hospitalization records received from the OTR, 529 (12.7%) were excluded prior to analysis. The final sample size was 3,633 subjects. Match level and death date were merged with the larger OTR data set. This information was used to calculate time to death and assign each individual a five-year vital status. Five years following injury, a total of 2,029 subjects (55.8%) were presumed to be alive (no evidence of death); 1,604 (44.2%) had documentation of death.

To verify the ability of the NDI and SSDI matching processes to identify the death of subjects in this study, the OTR supplied the names, birth dates, death dates, and social security numbers of persons known to have died in-hospital. Ten records per study year were submitted to the NDI. Test cases met the same study inclusion criteria ( $\geq 65$  years of age at the time of injury, injured between 1992 and 2000) but died prior to trauma center discharge. A total of 90 known-dead patients' records were submitted to the NDI along with those of subjects. Of the 90, there were 85 NDI confirmed matches. Match data for four other patients were off slightly, but the matches were easily verified with the SSDI. Only one known dead OTR control subject (1.1%) could not be accounted for with either the NDI or the SSDI.

## Hypothetical Controls

The U.S. Life Tables are published annually by the Centers for Disease Control. These public documents are available on the National Center for Health Statistics' web site, http://www.cdc.gov/nchs/products/pubs/pubd/lftbls/life/1966.htm. By consulting the corresponding actuarial table for each patient's year of injury, gender, and race, information regarding subjects' expected years of life remaining was identified.

In order to determine appropriate reference norms for comparison, OTR subjects

were each paired with a hypothetical control. Using existing U.S. Life Tables for the specific year of injury, a referent group was created, matching patients as closely as possible. The hypothetical controls were assigned the same birth date, gender, and race as their corresponding trauma patient. For a sample U.S. Life Table, see Appendix H. Remaining life expectancy and predicted five-year vital status (dead or alive) for the controls was determined by the life tables. Data from the matched, hypothetical control was considered each subject's five-year expected survival had the injury not occurred.

The NCHS began documenting year-by-year life expectancy projections in 1997. Prior to then, U.S. Life Tables reported actuarial data in five year intervals, instead of the more precise annual calculations. Therefore, accurate hypothetical controls could not be established for subjects injured before 1997. Only persons injured between 1997 and 2000 and could be matched for inclusion in the Aim 1 analysis. All subjects (1992-2000) were included in Aim 2 analyses.

## Variables

## Pre-injury patient predictor variables.

The three pre-injury patient variables examined were: Gender, Age at the Time of Injury, and Number of Systems with Preexisting Dysfunction (Table 3-1). Gender and birth date information were available for each patient in the Oregon Trauma Registry. Age at the Time of Injury was determined by subtracting birth date from injury date.

The OTR includes basic documentation of each patient's pre-injury medical status. These preexisting conditions (PECs) are extracted from hospital International

Classification of Diseases (ICD) codes, which are grouped into 14 body systems for reporting to the trauma registry. For the purposes of this study, the Unknown group was eliminated because it was too non-specific to contribute useful data. Also, given the age of the population of interest, the Pregnancy category was removed. Three items— Immunologic disease, Immunosuppressive therapy, and Immune-Post Splenectomy were

Table 3-1. Pre-Injury Patient Predictor Variables

Variable Name	Definition	Measure/Source	Variable Details/Values
Gender	Patient's gender	Dichotomous data extracted from the trauma registry.	Male/Female. This data element was used to match real patients with hypothetical controls for Aim 1.
Age at the Time of Injury	Age in years on the date of injury.	Continuous data extracted from the trauma registry.	Includes all patients in the Oregon Trauma Registry > 65 years old when injured.
Number of Systems with Preexisting Dysfunction	Total number of systems with a documented preexisting medical condition.	Continuous integer data derived from the trauma registry by counting the number of systems with a documented preexisting medical condition: • Cardiovascular • Respiratory • Liver/Anticoagulant medication • Renal • Diabetes • Neurologic • Psychiatric • Immunologic • Other	Potential range, 0 to 9

merged into a single Immunologic grouping. Anticoagulation Medication was combined with Liver, leaving a total of ten classifications. The final PEC classifications were: Cardiovascular, Respiratory, Liver/Anticoagulation Medication, Renal, Diabetes, Neurologic, Psychiatric, Immunologic, and Other.

The OTR reports preexisting medical conditions in each body system simply as present or absent, without reference to disease type, number, or severity. Therefore, for the purposes of analysis, the total number of reported body systems with a documented preexisting disease was summed into a new composite variable, Number of Systems with Preexisting Dysfunction, to provide an overall picture of each subject's pre-injury comorbidity status.

# Injury predictor variables.

Three injury variables were examined: Mechanism of Injury, Location of Injury Occurrence, and Injury Severity Score (Table 3-2). Mechanism of Injury is reported in the OTR as a narrative field that may contain much or little data, depending on the entering registrar. To facilitate comparisons, each record was individually reviewed and narrative data were coded into one of five basic mechanism of injury types: Falls, Motor Vehicle Collisions, Pedestrian/Bicyclist incidents, Penetrating injuries, or Miscellaneous.

Location of Injury Occurrence is described in the registry as one of 11 possible sites: Home, Farm, Logging, Industrial, Recreation/Sports, Street, Freeway/Highway, Public Building, Residential Institution, Other, and Unknown. Several similar locations were grouped for analysis. Farm, Logging, and Industrial were combined into a single

Table 3-2. Injury l	Predictor `	Variables
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Variable	Definition	Measure/Source	Variable Details/Values
Mechanism of Injury	A general description of cause of injury.	Categorical data extracted from trauma registry narrative data classified into general categories of injury.	<ul> <li>Five variables:</li> <li>Falls</li> <li>Motor vehicle collisions</li> <li>Pedestrian/bicyclist incidents</li> <li>Penetrating injuries</li> <li>Miscellaneous</li> </ul>
Location of Injury Occurrence	A general description of the site of injury occurrence.	Categorical data extracted from the trauma registry.	<ul> <li>Seven variables:</li> <li>Home</li> <li>Farm/logging/ industrial</li> <li>Recreation/sports</li> <li>Roadways</li> <li>Public building</li> <li>Residential institution</li> <li>Other/unknown</li> </ul>
Injury Severity Score	The most widely used anatomic scoring system for trauma patients. Data, collected retrospectively, is derived from ICD codes.	Discrete data extracted from the trauma registry and scored by the Oregon Trauma Registry's computer using standardized algorithms.	Severity range, 0-75

location, as were Street and Freeway/Highway (Roadways), as well as Other and

Unknown, thus reducing the final number of locations to seven.

Employing standardized algorithms, OTR software uses each patient's ICD codes

to generate an Injury Severity Score. This single score, computed across all anatomical

locations is used to determine the overall severity of each individual subject's traumatic

event. Potential Injury Severity Scores range from 0 to 75.

## Post-injury patient predictor variables.

The five post-injury patient variables examined were: ICU Length of Stay, Non-ICU Length of Stay, Grouped ICU Length of Stay, Discharge Disposition, and Discharge Limitations Score (Table 3-3). Non-ICU Length of Stay was calculated by subtracting each patient's ICU Length of Stay from their total hospital length of stay. Grouped ICU Length of Stay was divided into 0 days, 1-14 days, or greater than 14 days.

The OTR documents a brief assessment of patients' post-injury functional status. The three categories assessed are Feeding, Locomotion, and Communication. In each of these functional areas, abilities are scored as Independent, Moderately Independent, Moderately Dependent, or Dependent. For the purpose of analysis, these terms were converted to numeric scores (1-4) and summed to create a composite Discharge Limitations Score (range 3-12) providing a global representation of each subject's functional status at the time of trauma center discharge.

Table 3-3. Post-Injury Patient Predictor Variables

Variable	Definition	Measure/Source	Variable Details/Values
Non-ICU Length of Stay	Length of time a patient spent in an acute care faculty, but not in an intensive care unit, in days.	Discrete data extracted from the trauma registry calculated from hospital length of stay minus ICU length of stay.	Recorded as days
ICU Length of Stay	Length of time a patient spent in an intensive care unit, in days.	Discrete data extracted from the trauma registry.	Recorded as days
Grouped ICU Length of Stay	Length of time a patient spent in an intensive care unit grouped into 3 time periods	Categorical data extracted from the trauma registry.	Grouped into 3 time periods: • 0 days • 1-14 days • > 14 days
Discharge Disposition	Location to which the patient was sent following discharge from a trauma care facility	Categorical data extracted from the trauma registry.	<ul> <li>6 discharge locations:</li> <li>Home</li> <li>Home with home health</li> <li>Skilled nursing or intermediate care facility</li> <li>Rehabilitation center</li> <li>Acute care facility</li> <li>Other</li> </ul>
Discharge Limitations Score	The sum of scores assigned to each of 3 functional status domains	Data extracted from the trauma registry for the domains feeding, locomotion, & communication.	Summed score potential range, 3-12
		Each individual domain scored: 1 = Independent 2 = Moderately independent 3 = Moderately dependent 4= Dependent	

# Survival variables.

Two survival variables were used as patient outcomes: Post-Injury Survival Time, and Five-Year Vital Status (Table 3-4). Post-Injury Survival Time was calculated by subtracting injury date from death date. However, for the purposes of this study, Post-Injury Survival Time was truncated at five years. Patients still alive five years after injury were censored and assigned a Post-Injury Survival Time of five years. Subjects who died within the five-year interval were assigned a survival time that corresponded with their time from injury to death (< 5 years). All subjects were assigned a dichotomous Five-Year Vital Status based on whether they were alive or dead five years from the date of injury.

Variable Name	Definition	Measure/Source	Variable Details/Values
Post-Injury Survival Time	Elapsed time from injury to death in years, truncated at 5 years for patients still alive.	Continuous data. Injury dates from the trauma registry, death dates from the National Death Index and the Social Security Death Index.	Calculated by subtracting date of injury from date of death and capping the number at 5. Range 0-5.
Five-Year Vital Status	Five years post- injury, subjects were either alive or dead	Dichotomous data— dead or alive—derived by subtracting injury date from death date. Censored at five years post-injury.	For hypothetical controls (Aim 1), if life expectancy was < 5 years, controls were considered dead.

Table	3-4.	Surviva	l Variables

## Missing Data

For Aim 1, information regarding the two variables of interest (Post-Injury Survival Time and Five-Year Vital Status) was available for all subjects. Basic Aim 2 variables, such as birth date, gender, and mechanism of injury, were present for all patients.

In the final sample, a computer generated ISS was absent for 22 subjects. Missing Injury Severity Scores were manually calculated from Abbreviated Injury Scale score data, present for each patient. The OTR employes the Abbreviated Injury Scale (AIS) to quantify injury severity. Based on ICD codes, trauma registrars hand score each injury sustained by a patient on an integer scale of one to six, from minor to unsurvivable. Injury Severity Score (a global measure of injury severity) is obtained by summing the square of the scores for each of the three body regions with the highest AIS numbers. This technique is the methodology traditionally used to determine ISS. However, because the OTR uses software to calculate ISS directly from ICD codes, the computer scored ISS will not necessarily match a hand scored ISS, based on differences between registrarassigned and computer-assigned AIS values.

Subjects missing race data (n = 27) were entered as Unknown. Discharge Limitations Scores and Preexisting Medical Conditions information were missing for 6.1% and 8.7% of patients, respectively. Subjects with missing discharge or PEC data were excluded from analysis of these variables.

## Sample Size and Power Calculation

In Aim 1 (study years 1997 through 2000) 1,970 patients met inclusion criteria. The variable of interest for this aim was Post-Injury Survival Time. Power for Cox proportional hazards model is a function of sample size, event rate, and the effect size of the independent variable as reflected by the regression coefficient. Therefore, projecting an event (death) rate of .20 (20% of the sample dies within 5 years), with a sample size of 3,940 (1,970 trauma patients and 1,970 hypothetical controls), and an alpha level of .05, very small effect sizes can be detected (a hazard ratio of 1.07) with power of .80. If the event rate is .30, an even smaller effect size will be detected (hazard ratio of 1.05) with power of .80.

The Aim 2 sample included all 3,633 actual trauma patients. With power of .80 and an alpha level of .05, very small effect sizes (hazard ratios ranging from 1.05 to 1.08 when the covariates model explains 20% to 50% of the variance) can be detected for the independent variable of interest assuming an event rate of .20.

## Data Sources and Statistical Analysis by Specific Aim

# Aim 1

Quantify the impact of injury on the five-year survival of elderly patients in the Oregon Trauma Registry, who survived to trauma center discharge, compared to a hypothetical, age, race, and gender matched referent group. To accomplish Aim 1, Cox proportional hazards models were used to compare time from hospital discharge until death in elderly Oregon Trauma Registry survivors to the predicted remaining life expectancy of their hypothetical controls. Using the variable Post-Injury Survival Time, time from injury to death in subjects was compared to that of controls (as determined by actuarial tables). This method allowed for analysis of differences between the observed lifespan of patients in the sample and their expected lifespan.

Subjects alive five years from the date of injury—and hypothetical controls whose remaining life expectancy exceeded five years—were censored. In survival analysis, "censoring" refers to individuals who have not experienced the outcome of interest (in this case, death) by the end of the study period. This identified a hazard ratio for trauma patients versus controls that reflected differences in the rate of death within five years of hospital discharge.

### Aim 2

Identify patient and injury variables, present in the Oregon Trauma Registry, that predict five-year vital status in elderly trauma survivors.

This exploratory aim used bivariate and multivariate Cox proportional hazards models to examine predictors of post-injury survival time to answer the question: are there patient and injury variables, present at the time of trauma center discharge, which can forecast time to death? Predictor variables entered into the regression analyses included:

- Pre-injury patient characteristics—Gender, Age at the Time of Injury, and Number of Systems with Preexisting Dysfunction.
- 2. Injury characteristics—Mechanism of Injury, Location of Injury Occurrence, and Injury Severity Score.
- Post-injury patient characteristics—ICU Length of Stay, Non-ICU Length of Stay, Grouped ICU Length of Stay, Discharge Disposition, and Discharge Limitations Score.

Data for Aims 1 and 2 were retrieved from the Oregon Trauma Registry, the National Death Index, the U.S. Life Tables, and the Social Security Death Index as previously described. In contrast to Aim 1—in which 1,970 subjects injured between 1997 and 2000 were assigned a hypothetical, matched control—Aim 2 analyses involved only actual patients. Because matched controls were not required, all subjects (n = 3,633) were included in Aim 2 analyses.

Descriptive statistics were used for initial analysis of the data. All analyses were performed with the statistical software package, SPSS 16.0. Bivariate analyses were run to test the significance of each predictor variable. All significant predictors were then included in multivariate analyses to look at the relative importance of the predictors. The hazard ratios and associated significance identified patient and injury characteristics predictive of the rate of death in elderly OTR survivors.

## Chapter 4—Results

# Sample Description

**Pre-Injury Patient Characteristics** 

Gender, race, & age.

Subjects in this study were 53% male. As indicated by Figure 4-1, the ratio of male to female trauma patients changes dramatically through out the lifespan. Comparison data are not available for each of the study years (1992-2000), but information from the Oregon Trauma System's 2004-2005 Biennial Report graphically documents injury distribution by age and gender. Among 21-30 year olds, 75% of OTR

Figure 4-1. Age Group and Gender in the Oregon Trauma Registry



Oregon Trauma System 2004-2005 Biennial Report. Oregon Department of Human Services, 2006.

patients were male. This proportion steadily decreased until, by the age of 71, males represented only 48% of the total. Although the overall proportion of males in the population decreases with age, patterns of sexual distribution in the trauma population are chiefly related to risk-taking behaviors and mechanisms of injury, rather than to gender itself.

The study population was also overwhelmingly White (94%) (Table 4-1). Because there was so little variability between individuals, data were not analyzed by race or ethnicity. However, racial information was used when consulting the U.S. Life Tables to determine life expectancy for the hypothetical controls specific to Aim 1.

Forty five percent of all subjects were born in the 1920s, and 33 individuals (0.9%) were born prior to 1900 (Figure 4-2). The annual number of elderly trauma patients, and their mean age, steadily increased over the nine study years. In 1992 there were 300 Oregon Trauma Registry subjects who met inclusion criteria. By 2000, this number had risen to 512.



Figure 4-2. Year of Birth

Table 4-1. Sample Description

Gender								
_	Males	Females						
N	1,912	1,721						
%	53	47						
Race								
	White	Unknown	Asian	Hispanic	Other	Black	Nat Am	
N	3,418	88	47	26	25	22	7	
%	94.1	2.42	1.29	0.72	0.69	0.61	0.19	
Age at t	the Time of I	njury (years	6)					
	All	Males	Females		Ra	inge	> 85	> 100
Mean	76.8	75.8	78.8		Min.	Max.	570	6
SD	7.57	6.99	8.00		65	102	15.7%	0.17%
Mechar	nism of Injury	/						
	MVC	Falls	Ped/Bike	Misc	Pen			
N	1,844	1,207	287	202	93			
%	50.8	33.2	7.9	5.6	2.6			
Locatio	n of Injury O	ccurrence						
	Roadways	Home	Other/Unk	Res Inst	Farm/Log			
N	2,081	992	345	118	97			
%	57.28	27.31	9.50	3.25	2.67			
Anatom	ic Location o	of Injury						
	External	Chest	Low Ext	Head	Up Ext	Face/Neck	Spine	Abdomen
N	4,745	2,068	1,840	1,834	1,366	927	701	499
%	33.9	14.8	13.2	13.1	9.8	6.6	5.0	3.6
Mean Ir	njury Score b	by Anatomic	Location o	f Injury (Ra	ange 0-6)			
	External	Chest	Low Ext	Head	Up Ext	Face/Neck	Spine	Abdomen
	1.05	2.69	2.24	2.83	2.02	1.56	2.61	2.52
Distribu	tion of Injury	Severity S	cores (Rang	ge 0-75; M	ean 11.28;	SD 8.56 )		
	0-4	5-9	10-14	15-19	20-24	25-29	30+	
N	815	955	740	566	259	200	98	
%	22.4	26.3	20.4	15.6	7.1	5.5	2.7	
Disposi	tion at Disch	arge						
-	Home	H Health	SNF/ICF	Rehab	Acute	Other	AMA	
N	1,571	307	1,194	305	175	77	4	
%	43.2	8.5	32.9	8.4	4.8	2.1	0.1	

Nat Am = Native American; MVC = Motor vehicle collision; Ped/Bike = Pedestrian/Bicyclist; Misc = Miscellaneous; Pen = Penetrating; Other/Unk = Other/Unknown; Res Inst = Residential institution; Farm/Log = Farm/Logging/Industrial; External = External Surfaces; Low Ext = Lower Extremity; Up Ext = Upper Extremity; H Health = Home health/Rehabilitation; SNF/ICF = Skilled nursing facility/Intermediate care facility; Rehab = Rehabilitation center; Acute Care = Acute care facility (transfer); AMA = Left against medical advice

Between 1992 and 2000, the average age of subjects rose from 75.00 (SD 7.06) to 78.08 (SD 8.04) years (Table 4-2). Age at the time of injury ranged from 65 to 102 years, with an overall study mean of 76.8 years (SD 7.57). Individuals exceeding age 85 (the "old old") constituted 15.7% of the sample (n = 570) and 6 patients were over 100 years of age when injured. Age varied by gender. Men averaged 75.8 years (SD 6.99) while the mean age for women was 78.8 years (SD 8.00). This difference was statistically significant (p < .001), as were the gender differences between mean age at death. Male subjects died at an average age of 80.8 years (SD 7.28); mean age at death for females was 83.7 years (SD 8.02).

Year of Injury	Number of Subjects	Mean Age	SD
1992	300	75.00	7.06
1993	286	76.38	7.20
1994	311	75.31	6.94
1995	351	76.38	7.14
1996	415	77.41	7.64
1997	497	76.56	7.51
1998	457	77.25	7.75
1999	504	77.52	7.74
2000	512	78.08	8.04

Table 4-2. Number of Subjects and Age by Year of Injury

## Preexisting medical conditions.

There were a total of 3,298 preexisting medical conditions (PECs) reported in 2,308 subjects (Table 4-3). PEC data were missing for 8.7% (n = 316) of the sample. Cardiovascular disease accounted for 43% of documented PECs. The second most

commonly reported PEC was Other (37%, n = 1223). Diabetes and Respiratory system disorders occurred in 9.2% and 8.5% of subjects, respectively. Renal and Liver system diseases were each reported in less than 2% of patients and there were no documented cases of Neurologic, Psychiatric, or Immunologic dysfunction. The mean number of conditions for all subjects (minus those with missing data) was 0.99 (SD 0.83), but patients positive for PECs had an average of 1.43 conditions (SD 0.61).

Condition	Number	% of All PECs
Cardiovascular	1,417	43.0
Other	1,223	37.1
Diabetes	302	9.2
Respiratory	281	8.5
Renal	60	1.8
Liver	15	0.5
Neurologic	0	0.0
Psychiatric	0	0.0
Immunologic	0	0.0

Table 4-3. Preexisting Medical Conditions (PECs)

The PEC variable created for Aim 2 analysis was Number of Preexisting Systems with Dysfunction. Just under one third of subjects (27.8%) had no documented PECs; 40.4% had a PEC in one body system, 19.2% had two systems involved, 3.7% had three, and eight subjects (0.2%) were reported to have preexisting medical conditions in four body systems (Table 4-4).

Number of Conditions	Frequency	Percent of Total
0	1,009	27.8
1	1,469	40.4
2	696	19.2
≥ 3	143	3.9
Subjects Missing Data	316	8.7

Table 4-4. Count of Preexisting Systems with Dysfunction

#### *Pre-injury functional status.*

The OTR quantifies patients' pre-injury functional status by assessing locomotion and communication. Limitations in either of these two domains are scored dichotomously as absent or present, without reference to type or degree of disability. Data were missing in less than 0.2% of cases. Pre-injury locomotion limitations were reported in 189 subjects (5.2%). Communication limitations were documented in only 5 cases (0.1%). These data were used to compare group level pre- and post-injury functional status but were not include in specific aims analysis.

## Injury Characteristics

### Injury mechanism and location of occurrence.

Ninety seven percent of injuries sustained involved blunt trauma; less than 3% of patients experienced penetrating injuries. Motor Vehicle Collisions constituted half of all trauma mechanisms (50.8%) and Falls were responsible for an additional one third of injuries (33.2%) (Table 4-1). Pedestrian/Bicyclist events made up almost 8% of the sample with Penetrating and Miscellaneous injuries accounting for the remainder of

trauma mechanisms experienced by subjects.

Consistent with the finding that motor vehicle collisions were responsible for the majority of injuries, Roadways were the most common location of injury occurrence (57.3%) followed by Home (27.3%) (Table 4-1). Less frequent (2.7%) were injuries that occurred at Farming/Logging/Industrial sites. Residential Institutions were the traumatic event location for 3.2% (n = 118) of subjects. Virtually all residential institution cases involved falls. Examples from the cause detail narrative include: "got tangled in sheets and fell from bed"; "fell off commode"; "unwitnessed fall from wheelchair"; "fell over mop bucket"; "fell from motorized wheelchair"; and "fell striking head on heating unit".

Fifty three subjects (< 1%) were described as involved in Recreational or Sports activities at the time of injury. Descriptions of activities included: "go-cart rollover"; "struck tree while skiing"; "pilot flipped single engine plane while trying to land"; "run over by golf cart"; "arm caught in gyrocopter propeller"; and "crash into cliff parasailing".

Mechanisms of injury among OTR patients vary markedly by age group. Figure 4-3 illustrates incidence of injury related to specific mechanisms, according to patient age. After several post-young adult decades of declining rates, persons over 60 years experience a dramatic increase in both motor vehicle collisions and falls compared to other age classes.


Figure 4-3. Mechanism of Injury by Age Group in the Oregon Trauma Registry

Oregon Trauma System 2004-2005 Biennial Report. Oregon Department of Human Services, 2006.

#### Anatomic location of injury

The OTR employes a complex system of classifying and scoring up to 10 injuries per subject, in any of 14 body regions, using a severity scale of 1-6. For the purposes of this study, the anatomic locations C-Spine, T-Spine, L-Spine, and Spine were pooled into a single Spine category. The Face and Neck regions were also combined. Hand and Arm were merged to form an Upper Extremity group, and Leg and Pelvic Girdle were joined as Lower Extremity & Pelvis. The Abdominal, Chest, Head, and External Surfaces classifications were unchanged. Category compression was done to facilitate group-level description of injury location, frequency, and severity across all subjects. Subjects sustained a mean of 3.85 injuries (Figure 4-4). External Surfaces (the skin) was the location of the greatest number of reported injuries, followed by the Chest, Lower Extremities & Pelvis, Head, Upper Extremities, Face & Neck, Spine, and Abdomen (Table 4-1).



Figure 4-4. Frequency of Injury to Each Body Region

Mean injury scores for each body region were calculated by summing all regional injury severity scores and then dividing by the total number of injuries per body region. Mean injury scores were lowest for External Surfaces (1.05) and highest for the Head (2.83) (range 1-6) (Figure 4-5). Mean scores for Chest, Spine, Abdomen, and both Lower and Upper Extremities, each exceeded 2.00. Five subjects had an injury score of 6 to one body region (1 Chest, 2 Spine, and 2 Head), a score defined as "unsurvivable".

# Injury Severity Scores

An Injury Severity Score (ISS), the variable used for Aim 2 analysis, is a composite score of each patient's wounds designed to facilitate comparison of injury severity across subjects, anatomic locations, and mechanisms of injury. Individual subject scores ranged from 0 to 50. The mean ISS for all subjects was 11.28 (SD 8.56) with a median score of 10.00 but a mode of 1.00. Male patients demonstrated a slightly higher but statistically significant mean ISS (11.58) (SD 8.60) than did females (10.95) (SD 8.53) (p = .03). One quarter of subjects (n = 815, 22.4%) had extremely low Injury Severity Scores (0-4), half (48.7%) scored less than ten, and 69% of the sample had an ISS below 15. In only 8% of cases (n = 298) was ISS 25 or higher (Figure 4-6). Subjects'



Figure 4-5. Mean Injury Severity by Body Region

Anatomic Location of Injury

relatively low scores are consistent with data from current OTR reports indicating that both injury incidence and severity peak in the adolescent and young adult years and decline sharply with age (Figure 4-7).

Figure 4-6. Distribution of Injury Severity Scores Using the National Trauma Data Bank Severity Definitions



No injuries (ISS = 0) were documented in 76 subjects (2%). Many of these patients were simply "found down" and entered into the trauma system. Their conditions were later ascribed to a non-trauma etiology. Other persons in the No Injury group experienced low level falls or were involved in motor vehicle collisions. On evaluation,



Figure 4-7. Injury Severity Score and Incidence by Age in the Oregon Trauma Registry

Oregon Trauma System 2004-2005 Biennial Report. Oregon Department of Human Services, 2006.

no actual injuries were identified. These individuals represent trauma system overtriage, a moderate degree of which is considered both necessary and acceptable to avoid missed injuries. Subjects with an ISS of 0 were retained in the sample and included in the analyses because they constitute a small but important segment of overall trauma system activity. Although in retrospect no injuries were discovered, these patients met initial trauma system activation criteria and represent one end of the trauma acuity spectrum.

## Post-Injury Patient Characteristics

Trauma center admission.

The 3,633 subjects in this study were treated during a total of 3,984 facility visits, indicating that 351 (almost 10%) required interfacility transfer. Fifty five percent of subjects were admitted to a Level 1 trauma centers at some point during their care. Six patients received treatment only at a non-trauma center facility (Table 4-5).

	Patients Each	Treated at Level	Highest Care Re	Highest Level of Care Received		
Trauma Center Level	Number	Percent	Number	Percent		
Level 1	1,998	50.2	1,998	55.0		
Level 2	632	15.9	616	17.0		
Level 3	1,050	26.4	853	23.5		
Level 4	298	7.5	160	4.4		
Non trauma center	6	0.2	6	0.2		
Total	3,984		3,633			
Transfers	351					

Table 4-5. Trauma Center Usage

# ICU and non-ICU lengths of stay.

Total hospital length of stay (LOS) ranged from 0 to 116 days; mean LOS was just over one week (8.08 days, SD 10.28). Two thirds of patients (66.3%) were admitted for less than seven days and 86% were discharged in under two weeks. Mean intensive care unit (ICU) LOS for subjects who were admitted to an ICU was 7.79 days (SD 6.38) with a range of 0 to 116 days. Eighty percent spent less than one week in intensive care. For purposes of analysis, ICU LOS (days) and Non-ICU LOS (days) were the variables used. ICU LOS data were also grouped into Less Than 14 Days and More Than 14 Days (Table 4-6). Half of all subjects (51%) spend some time in an intensive care unit but less than 5% required more than two weeks of intensive care.

	Number	Percent
No ICU days	1,608	44.3
1-14 days	1,856	51.1
> 14 days	169	4.7

## Discharge disposition & functional limitations at discharge.

Half (51.7%) of all patients in this study were sent to a home environment following trauma center discharge, although 8.5% required home health services (Figure 4-8). One third of subjects (32.9%) were discharged to a skilled nursing facility or intermediate care facility, and 2.5% went to a rehabilitation center. Seventy seven of the 118 patients whose injuries occurred in a residential care facility (75%) were discharged to a skilled nursing, intermediate care, or acute care facility.

Post-injury, most patients' feeding (82.3%), locomotion (62.5%), and communication (88%) abilities were scored as Functions Independently or Moderately Independently. However, pre-injury, 95% of patients experienced no recorded locomotion limitations and 98% had no documented communication limitations.

Although analysis of specific functional limitations was not included in Aim 2, group level pre-injury function was compared to group level post-injury function to examine outcome trends (Table 4-7). Following injury, the number of patients with a

Figure 4-8. Discharge Disposition



Locomotion limitation (moderately independent, moderately dependent, or dependent) increased from 5% to 37% and the number with a Communication limitation rose from 2% to 12%. Pre-injury Feeding functional status is not recorded by the OTR, but post-injury 18% of patients experienced some degree of limitation.

Table 4-7. Patients with Any Functional Status Limitations Reported Pre- and Post-Injury

	Locomotion	Communication	Feeding
Pre-Injury	5%	2%	Not Assessed
Post-Injury	37%	12%	18%

Calculated post-injury Discharge Limitations Scores (the sum of the scores for the three ability domains) were available for 94% (n = 3412) of the sample and were used for Aim 2 analysis. Data indicated that 42% of patients were discharged without any limitations in feeding, locomotion, or communication. However, approximately 10% of

subjects had a score denoting moderate or severe dependence in two or more of the functional domains ( $\geq$  7).

# Relationships between pre- and post-injury variables.

To examine relationships between preexisting medical conditions and post-injury variables, two cross-tabulations were run. The first (Table 4-8) identified the relationship between preexisting medical conditions and discharge location. The second (Table 4-9)

Table 4-8.	. The Relationship	Between	Preexisting	Medical	Conditions	and Disch	narge
Location							

		Tra	auma Co	enter Dis	charge	Locatio	on	
	Number of Body Systems with PECs	Home	Home Health	SNF-ICF	Rehab	Acute Care	Other	Total Subjects Per Number of Conditions
Number of Subjects		507	75	291	91	29	16	1,009
% Discharged With 0 Conditions	0	35.8	26.2	26.3	32.2	19.2	21.1	
% with 0 Conditions By DC Location		50.2	7.4	28.8	9.0	2.9	1.6	
Number of Subjects		637	132	472	113	71	44	1,469
% Discharged With 1 Conditions	1	45.0	46.2	42.7	39.9	47.0	57.9	
% with 1 Conditions By DC Location		43.4	9.0	32.1	7.7	4.8	3.0	
Number of Subjects		225	62	288	65	40	16	696
% Discharged With 2 Conditions	2	15.9	21.7	26.1	23.0	26.5	21.1	
% with 2 Conditions By DC Location		32.3	8.9	41.4	9.3	5.7	2.3	
Number of Subjects		47	17	54	14	11	0	143
% Discharged With 3 Conditions	3	3.3	5.9	4.9	4.9	7.3	0	
% with 3 Conditions By DC Location		32.9	11.9	37.8	9.8	7.7	0.0	
Total Subjects Per Discha	rge Location	1,416	286	1,105	283	151	76	3,417

PECs = Preexisting Medical Conditions; SNF-ICF = Skilled nursing facility/intermediate care facility. Rehab = Rehabilitation center

highlights the relationship between preexisting medical conditions and functional status at discharge.

		Discharge Limitations Score							
		3	3	4-	6	7	-9	10-	12
		No De	eficits	its Mild Deficits		Moderate Deficits		Severe Deficits	
		#	%	#	%	#	%	#	%
Number of Body Systems with PECs	0	451	34.3	399	29.9	59	22.5	49	25.7
	1	583	44.3	566	42.4	140	53.4	81	42.4
	2	238	18.1	302	22.6	57	21.8	49	25.7
	3	44	3.34	67	5.02	6	2.29	12	6.28
7	otals	1,316		1,334		262		191	

Table 4-9. The Relationship Between Preexisting Medical Conditions and Discharge Limitations Scores

PECs = Preexisting Medical Conditions;

### Survival Outcome Variables

Five-year vital status & post-injury survival time.

Overall study mortality was 44.2%; 55.8% of patients were still alive five years after injury. Twenty four patients were dead within the first week; 160 died within a month, and almost 15% of the study sample (n = 543) had succumbed within one year of their traumatic incident (Table 4-10).

Time Elapsed	Cumulative Mortality				
Post-Discharge	Number	Percentage	Number	Percentage	
0-7 Days	24	0.66	24	0.66	
1 Week-1 Month	136	3.74	160	4.40	
1-3 Months	133	3.66	293	8.06	
3-6 Months	98	2.70	391	10.76	
6 Months-1 Year	152	4.18	543	14.95	
1-2 Years	254	6.99	797	21.94	
2-3 Years	297	8.18	1,094	30.11	
3-4 Years	280	7.71	1,374	37.82	
4-5 Years	230	6.33	1,604	44.15	
Alive at 5 Years	2,029	55.8			

Table 4-10. Time to Death, All 3,633 Subjects

Over the nine year study period, the percent of patients who had died at both one year and five years following injury trended upward. However, mean subject age also increased over the same time period (Table 4-11).

	Number of	umber of % Dead Post-Injury		
Year of Injury	Subjects	Mean Age	1 Year	5 Years
1992	300	75.0	13	36
1993	286	76.4	14	43
1994	311	75.3	12	41
1995	351	76.4	16	42
1996	415	77.4	13	47
1997	497	76.6	15	38
1998	457	77.3	15	47
1999	504	77.5	16	51
2000	512	78.1	18	47

Table 4-11. 5-Year Mortality by Study Year

## Aim 1 Results

## Death within Five Years of Injury

To determine a five-year survival hazard ratio for elderly OTR patients who survived to trauma center discharge, actual subjects were compared to a hypothetical, age, race, and gender matched referent group derived from the U.S. Life Tables. The Aim 1 sample consisted of 1,970 subjects (injured between 1997 and 2000) and 1,970 hypothetical controls. No patients were censored due to missing data.

Cox proportional hazards models were used to test whether subjects' time until death was significantly different from their hypothetical, matched controls. Case versus control was the independent variable and Post-Injury Survival Time the dependent variable. Both case and control subjects who did not die within five years were censored at five years. No covariates were included in the model because the hypothetical controls were matched on age, race, and gender.

The overall model was significant (p <.001). The hazard ratio of case versus control was 6.26 (95% CI, 5.90-9.32). This indicates that study subjects were 6.26 times (or 526%) more likely to die in the five-year period following traumatic injury than were their age, race, and gender matched controls (Figure 4-9). Mean time to death for controls was 4.05 years (SD 0.67), while mean time to death for study subjects was 2.03 years (SD 1.54). Only 54.3% of OTR cases were alive five years post-injury, whereas 90.1% of hypothetical, matched controls survived the study period (Table 4-12).

Separate Cox proportional hazards models were run for male and female subjects. Marked gender differences were apparent. Despite the fact that male subjects were significantly younger than females at the time of injury (75.8 years versus 78.8 years) (p <.001), the hazard for death in males (n = 1,912) in the five years following injury was 7.42 times that of their hypothetical, matched controls (p <.0001) while the hazard for females (n = 1,721) was 5.31 times greater than controls (p <.0001).



Figure 4-9. Hazard Ratio for Death within 5 Years of Injury, All Subjects 1997-2000

	Time From Injury (Years)	Number Alive at the Start of the Year	Number of Deaths During the Year	Cumulative Percent Surviving
Hypothetical	0-1	1970	0	100%
Controls	1-2	1970	0	100%
	2-3	1970	20	99%
	3-4	1950	52	96%
	4-5	1898	123	90%
Actual	0-1	1970	315	84%
Subjects	1-2	1655	140	77%
	2-3	1515	165	69%
	3-4	1350	156	61%
	4-5	1194	125	54%

Table 4-12. Life Table Comparing Survival Time for All 1997-2000 Subjects and	Their
U.S. Life Table Matched, Hypothetical Controls	

# Aim 2 Results

Analyses were conducted using all injured geriatric patients and subsets of patients to look for covariates significantly associated with decreased survival time in the first five years following trauma center discharge. All 3,633 subjects injured between 1992 and 2000 were included in Aim 2 analysis. Aim 2 explored relationships among both patient and injury variables, present in the Oregon Trauma Registry, which might predict five-year post-injury life expectancy in elderly Oregon Trauma System survivors. Bivariate and multivariate Cox proportional hazards models were used to examine associations between various patient and injury characteristics and years from discharge to death after traumatic injury.

# **Bivariate Models**

Pre-injury patient variables.

Cox proportional hazards model was used to individually test the effect of three pre-injury independent variables: Gender, Age at the Time of Injury, and Number of Systems with Preexisting Dysfunction. Post-Injury Survival Time was the dependent variable. All three variables were significantly related to survival. (Tables 4-13 & 4-14).

The hazard ratio for death within five years of injury was 16% greater for males than for females. Age at the Time of Injury had a significant impact on survival. For every one year over the age of 65 at the time of injury, patients were 5.8% more likely to

	Change From Previous Step		
	Chi-square	df	<i>p</i> Value
Pre-Injury Patient Variables			
Gender	8.818	1	0.003
Age at the Time of Injury	293.065	1	<.0001
Preexisting Systems Dysfunction	79.641	1	<.0001
Injury Variables			
Mechanism of Injury	137.486	4	<.0001
Location of Injury Occurrence	244.601	4	<.0001
Injury Severity Score	0.093	1	.761
Post-Injury Patient Variables			
Total ICU Length of Stay	9.030	1	0.003
Non-ICU Length of Stay	4.775	1	0.029
Weeks in ICU	7.948	2	0.019
Discharge Disposition	176.920	3	<.0001
Discharge Limitations Score	266.410	3	<.0001

Table 4-13. Omnibus Tests of the Aim 2 Model

die within five years. For each additional body system with a Preexisting Dysfunction, the five-year mortality hazard increased by 32%, compared to patients with no preexisting system dysfunction.

## Injury variables.

Bivariate Cox proportional hazards models were used to examine the impact of three injury variables on survival: Mechanism of Injury, Location of Injury Occurrence, and Injury Severity Score. Post-Injury Survival Time was the dependent variable. The first two variables were significantly related to five-year vital status (Tables 4-13 & 4-14). Using Motor Vehicle Collisions as the referent group (the most common mechanism) mechanism of injury was significant overall, but only Fall victims had a significantly different survival rate compared to Motor Vehicle Collisions. The hazard ratio for Falls was 1.88, indicating that subjects injured by falling had an 88% greater five-year mortality than did individuals involved in motor vehicle collisions.

Roadways, as the most frequent location of injury occurrence, were selected as the referent variable. Compared to Roadways, persons suffering traumatic injuries at a Farm/Logging/Industrial site were only half as likely (hazard ratio 0.49) to be dead five years after injury. However, those injured at Home or in a Residential Institution were respectively 1.7 and 5.1 times more likely to die within the same time period. Injury Severity Score had a no significant impact on post-injury survival time.

## Post-injury patient variables.

The effects of five post-injury patient variables on time to death were independently tested with Cox proportional hazards model, using Post-Injury Survival Time as the dependent variable. These variables were: Non-ICU Length of Stay (days), ICU Length of Stay, Grouped ICU Length of Stay, Discharge Disposition, and Discharge Limitations Score. All five variables were significantly related to survival (Tables 4-13 & 4-14).

Each day spent in a non-intensive care unit increased the hazard of five-year mortality by 0.8%; each day spent in an intensive care unit increased the hazard by 1.1%. Compared to patients not treated in an ICU, those admitted to intensive care for fewer than two weeks had a 12% increase in mortality, while subjects with ICU stays exceeding two weeks experienced a 30% increase in their five-year hazard for death.

Discharge disposition following trauma center discharge also predicted five-year vital status. Compared to patients who went Home without assistance, the hazard ratio for those who went home but required Home Health Services was 1.22; persons discharged to a Skilled Nursing Facility/Intermediate Care Facility had a 1.93 five-year hazard of death; and subjects who were discharged from a trauma center but admitted to another Acute Care facility had a hazard ratio 2.8 times greater than those discharged Home.

Functional limitations at the time of trauma center discharge were significantly related to five-year vital status. Compared to individuals with no post-injury functional limitations (Discharge Limitations Score = 3), persons with scores of 4-6, 7-9, and 10-12 had increased mortality hazards of 1.2, 2.1, and 4.6, respectively.

			Hazard	95% CI for Exp(B)	
Variables	df	<i>p</i> Value	Ratio	Lower	Upper
Pre-Injury Patient Variables					
Gender	1	0.003	1 160	1 052	1 281
Age at the Time of Injury	1	< 0001	1 058	1.052	1 065
Preexisting Systems Dysfunction	1	<.0001	1.318	1.241	1.399
Injury Variables					
Motor Vehicles		<.0001			
Falls	1	<.0001	1.878	1.689	2.089
Pedestrian/Bicyclist	1	.397	1.089	0.894	1.327
Penetrating	1	.016	1.456	1.074	1.976
Miscellaneous	1	.112	1.202	0.958	1.508
Location of Injury Occurrence					
Roadways	4	<.0001			
Farm/Logging/Industrial	1	0.002	0.490	0.314	0.763
Home	1	<.0001	1.703	1.526	1.901
Residential institution	1	<.0001	5.064	4.118	6.226
Other/Unknown	1	0.005	1.275	1.076	1.512
Post-Injury Patient Variables					
ICU Length of Stay (days)	1	0.001	1.011	1.004	1.017
Grouped ICU Days					
No ICU Stay	2	0.018			
Less than 14 days	1	0.024	1.123	1.015	1.243
More than 14 days	1	0.026	1.293	1.032	1.620
Discharge Disposition					
Home	4	.000			
Home health/Rehab	1	.041	1.224	1.008	1.486
SNF/ICF	1	.000	1.930	1.724	2.162
Acute care	1	.000	2.816	2.303	3.444
Other	1	.780	1.029	.840	1.261
Discharge Limitations Score					
3	3	<.0001			
4-6	1	0.002	1.203	1.071	1.352
7-9	1	<.0001	2.070	1.740	2.461
10-12	1	<.0001	4.612	3.886	5.474

Table 4-14. Aim 2 Hazard Ratios for Significant Predictors in the Bivariate Analyses of 5-Year Survival

ICU = Intensive care unit; SNF/ICF = Skilled nursing facility/Intermediate care facility

## Multivariate Models

Of the initial variables tested, only Injury Severity Score proved non-significant. Excluding Grouped ICU Days, all other pre-injury, injury, and post-injury variables significant in the bivariate analyses were entered as covariates into a Cox proportional hazards model. These nine variables were: Gender; Age at the Time of Injury; Number of Preexisting Systems Dysfunction; Mechanism of Injury; Location of Injury Occurrence; Non-ICU Length of Stay, ICU Length of Stay, Discharge Disposition, and Discharge Limitations Score. Each was tested using the same variable order as in the bivariate analyses. In the initial multivariate model, Mechanism of Injury; Non-ICU Length of Stay, and ICU Length of Stay were all nonsignificant and were dropped from further analysis (Table 4-15).

A trimmed model was run to examine the relative importance of the remaining six variables (Table 4-16). The final model consisted of Gender, Age at the Time of Injury, Number of Preexisting Systems Dysfunction, Location of Injury Occurrence, Discharge Disposition, and Discharge Limitations Score. Both the overall model and each of the final covariates were significant (p < .0001). In this final model, the hazard ratio for male gender was 1.39, indicating that men were nearly 40% more likely than women to die within five years of injury. Age also had a significant impact on survival. For every 1 year increase in age, subjects were 4.8 % more likely to die within the study interval. Each body system with preexisting dysfunction (prior to the time of injury) was associated with a 20% rise in the probability of death within five years. Overall, Location of Injury Occurrence, Discharge Disposition, and Discharge Limitations Score were significant but their impact varied by specific variables.

	df	<i>p</i> Value	Hazard Ratio	Lower	Upper
Gender	1	<.001	1.381	1.233	1.548
Age at the Time of Injury	1	<.001	1.048	1.040	1.056
Preexisting Systems Dysfunction	1	<.001	1.207	1.131	1.289
Mechanism of Injury					
Motor Vehicles	4	.104			
Falls	1	.029	1.306	1.027	1.661
Pedestrian/Bicyclist	1	.925	.989	.795	1.231
Penetrating	1	.025	1.590	1.059	2.387
Miscellaneous	1	.543	1.099	.811	1.487
Location of Injury Occurrence					
Roadways	4	<.001			
Farm/Logging/Industrial	1	.001	.429	.259	.711
Home	1	.770	1.037	.812	1.324
Residential institution	1	<.001	2.391	1.730	3.303
Other/Unknown	1	.627	1.064	.827	1.369
Non-ICU Length of Stay (days)	1	.970	1.000	.990	1.010
ICU Length of Stay (days)	1	.879	1.001	.991	1.010
Discharge Disposition					
Home	4	<.001			
Home health/Rehab	1	.529	1.072	.864	1.329
SNF/ICF	1	.016	1.229	1.039	1.453
Acute care	1	<.001	1.659	1.280	2.150
Other	1	.206	.855	.670	1.090
Discharge Limitations Score					
3	3	<.001			
4-6	1	.539	1.049	.901	1.220
7-9	1	.001	1.479	1.185	1.846
10-12	1	<.001	3.002	2.376	3.793

Table 4-15. Aim 2 Hazard Ratios for a Multivariate Model Predicting 5-Year Su	ırvival
Following Geriatric Trauma	

	df	<i>p</i> Value	Hazard Ratio	Lower	Upper
Gender	1	.000	1.387	1.239	1.553
Age at the Time of Injury	1	.000	1.048	1.040	1.055
Preexisting Systems Dysfunction	1	.000	1.206	1.130	1.287
Location of Injury Occurrence					
Roadways	4	.000			
Farm/Logging/Industrial	1	.003	.481	.296	.780
Home	1	.000	1.320	1.166	1.495
Residential institution	1	.000	3.070	2.415	3.903
Other/Unknown	1	.010	1.275	1.060	1.533
Discharge Disposition					
Home	4	.000			
Home health/Rehab	1	.458	1.084	.875	1.343
SNF/ICF	1	.010	1.241	1.053	1.461
Acute care	1	.000	1.676	1.297	2.165
Other	1	.214	.859	.676	1.092
Discharge Limitations Score					
3	3	.000			
4-6	1	.647	1.036	.891	1.203
7-9	1	.000	1.472	1.186	1.827
10-12	1	.000	2.999	2.396	3.754

Table 4-16. Final Aim 2 Multivariate Hazard Ratios Model for a Predicting 5-Year Survival Following Injury in Geriatric OTR Subjects

# Summary of Findings

The specific aims of this project were to: 1) quantify the impact of injury on fiveyear vital status and 2) identify patient and injury variables, present at the time of trauma center discharge, that predicted the five-year vital status of elderly Oregon Trauma System survivors. Subjects, selected from the Oregon Trauma Registry, were over the age of 65 at the time of injury and were discharged alive from an Oregon Trauma System hospital. During the study years (1992-2000) 3,633 patients met inclusion criteria. The sample was 53% male and 94% Caucasian. Mean age at the time of injury was 76.8 years but increased over the nine study years and was higher in women. Sixty three percent of patients had one or more preexisting comorbidities at the time of injury. No pre-injury locomotion or communication limitations were reported in 95% of cases. Motor vehicle collisions and falls were the mechanisms responsible for 50% and 33% of injuries, respectively. Roadways (57.3%) and homes (27.3%) were the most frequent locations of injury.

Subjects sustained a mean of 3.85 injuries, most commonly to the external surfaces. However, the anatomic locations that suffered the highest mean injury scores were the head, chest, and spine. Nearly half of all patients had low Injury Severity Scores (0-9, mild injury) and only 8% achieved a score of 25 or higher (very severe injury). Over half of all patients (55%) were treated in a Level 1 trauma facility at some time during their hospitalization, 351 interfacility transfers were performed, and six patients were never treated in a designated trauma center.

Average hospital length of stay was eight days. Fifty six percent of cases required intensive care unit admission but 92% of these patients spent less than two weeks in an ICU. Half (51.7%) of all subjects were discharged home; one third (32.9%) were discharged to a skilled nursing or intermediate care facility. At the time of discharge, locomotion, communication, and feeding functional limitations were present in 37%, 12%, and 18% of subjects, respectively.

Only 54.3% of OTR cases injured between 1997 and 2000 were alive five years post-injury, whereas 90.1% of their hypothetical, matched controls survived this same time period. Mean time to death for controls who died was 4.05 years, while mean time to death for cases who died was 2.03 years. Cox proportional hazards model was used to identify risk of death. The hazard ratio for death within five years of injury for subjects injured between 1997 and 2000 was 6.26, compared to age, race, and gender matched actuarial controls. The five year hazard ratio varied by gender: males 7.42, females 5.31. Of the pre-injury, injury, and post-injury variables tested, only Gender, Age at the Time of Injury, Preexisting Systems Dysfunction, Location of Injury Occurrence, Discharge Disposition, and Discharge Limitations Score predicted five-year vital status in the final, multivariate model.

Hazard ratios for the significant pre-injury variables were as follows: gender (male versus female), 1.39; age at the time of injury, 1.05 (per year of age beyond 65 years); and preexisting systems dysfunction, 1.21 (per system). Hazard ratios for the variables Location of Injury Occurrence, Discharge Disposition, and Discharge Limitations Score were examined. Compared to those injured on roadways, persons whose trauma occurred in a residential institution had a hazard ratio of 3.07 whereas those injured at a farm, logging, or industrial site experienced a hazard ratio of 0.48. Compared to a Home discharge location, the five-year mortality hazard for subjects discharged to a skilled nursing or intermediate care facility was 1.24 and the hazard ratio for those discharged to an acute care facility was 1.68. Discharge Limitations Scores also predicted five-year vital status. Compared to subjects with a Discharge Limitations Score of 3 (no limitations) persons with scores of 7-9 or 10-12 had hazard ratios of 1.47 and 3.00, respectively.

#### Chapter 5—Discussion

#### Unique Aspects of the Study

Although high in-hospital mortality rates following injury in seniors have been well documented, there is a dearth of data regarding the long-term impact of trauma on the life expectancy of geriatric injury survivors. Several studies have reported significant mortality in older adults in the weeks, months, and years after trauma center discharge, but few researchers have compared the incidence of death in trauma survivors to that of population-based norms, and none have done so on a statewide, systemwide basis. Investigators have analyzed survival in persons with specific types of injuries (e.g., hip fracture, head trauma), with a certain degree of injury severity (e.g., ISS > 12), from a single trauma center, or across multiple trauma systems. This is the first large scale study to employ actuarial data to identify the increased long-term burden of mortality on geriatric trauma survivors—across all injury types, mechanisms, and severities—in order to provide a comprehensive perspective of post-trauma outcomes in a state with an inclusive and well-established trauma system.

There were two key findings in this study. First, data supported the proposed quinta-modal model of death in geriatric trauma patients. There is a quantifiable, ongoing, long-term (five year) relationship between trauma and shortened lifespan in Oregon Trauma Registry (OTR) survivors who were over the age of 65 years at the time of injury. The second key finding was that this long-term relationship between trauma and death is largely influenced by host factors, rather than factors directly associated with the injuring event. Other than demographic characteristics (age and gender), the only variables that were significantly related to long-term survival were those that either directly measured, or indirectly suggested, subjects' physiological or functional status.

### The Quinta-Modal Model of Death in Geriatric Trauma Patients

The theoretical model that formed the basis for this investigation (Figure 5-1) was Trunkey's seminal tri-modal model of trauma deaths (within minutes, hours, and days of injury), first proposed in the 1980s (Trunkey, 1983). In the late 1990s, researchers posited a quadra-modal distribution of post-traumatic deaths to explain the persistent, ongoing mortality risk observed throughout the first post-injury year (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998). The 15% one-year mortality noted in the present study supports the existence of this fourth death peak in older adults. However, the goal of the current investigation was to examine the existence of a hypothesized late effect of injury on survival in the geriatric population by analyzing mortality patterns up to five years after trauma center discharge.

An ongoing association between trauma and reduced life expectancy, long past the initial event, has been suggested by several researchers who noted a persistently high incidence of death even years following injury (Battistella et al., 1998; Gallagher et al., 2003; R. Morris et al., 2000; Olson et al., 2003; van der Sluis et al., 1996). Regrettably, only a few investigators have compared their elderly subjects' post-trauma lifespan to population-based estimates of remaining life expectancy (Gubler et al., 1997; McGwin et al., 2000; Rose & Maffulli, 1999; Rozental et al., 2002) and only Gubler (1997) and



Figure 5-1. Theoretical Model: The Quinta-Modal Model of Geriatric Trauma Mortality

McGwin (2000) examined patients with multi-system injuries. Comparing subjects' life expectancy to population-based norms is crucial when studying geriatric trauma survivors because of the inherently high incidence of death in the elderly. Without appropriate normative comparisons it is impossible to identify elevated mortality rates in the geriatric population and excess deaths can easily be attributed to the natural aging process.

The present study employed a large, statewide database to examine time to death in the five years following injury in elderly trauma survivors, and compared actual time to death with projected estimates of remaining lifespan based on nationwide actuarial projections. Subjects failed to meet actuarial norms for life expectancy. Geriatric trauma survivors experienced 6.2 times (95% CI, 5.90-9.32) the hazard of death within five years of injury (compared to hypothetical, matched controls) confirming that seniors in this sample carried a substantial and ongoing mortality risk that persisted at least five years after the traumatic event. Although model testing was never the aim of this investigation, these findings can contribute to, and suggest directions for, future model development.

#### Implications for practice and theory.

Since Trunkey's tri-modal model of trauma deaths was first introduced three and a half decades ago (Trunkey, 1983), targeted improvements in pre-hospital and inhospital trauma care have served to substantially reduce mortality in the first, second, and third death peaks, particularly in younger populations. In fact, a recent Scandinavian study examining patterns of death following trauma in 260 patients (mean age = 45.8 years  $\pm$  25.1) found only a bimodal distribution of in-hospital death. The first peak occurred at one hour and accounted for nearly 30% of all deaths (Trunkey's "Golden Hour"). The second peak occurred between days one and seven, and was responsible for about 15% of deaths (Soreide et al., 2007). Other recent researchers have observed and reported similar trends (Acosta et al., 1998; Demetriades et al., 2005; Demetriades et al., 2004; Meislin et al., 1997)

By employing an inclusive approach to the needs of the injured patient, trauma centers and trauma systems have made measurable differences in survival in the last few decades. The implementation of rapid and advanced pre-hospital care, aggressive resuscitation protocols, and early surgical intervention have substantially reduced both pre-hospital and in-hospital deaths (Celso et al., 2006; MacKenzie et al., 2006; Mann et al., 1999). Now, with long-term mortality data available, investigators and clinicians can

identify and target interventions designed to increase geriatric survival during the postdischarge phase as well.

## Host Status as a Predictor of Long-Term Survival

### Pre-injury host status.

Research has shown an association between advancing age and reduced survival following injury, but little is known about the effects of physiologic reserve, resilience, and frailty on long-term outcomes (Jacoby, Ackerson, & Richmond, 2006). Findings from this investigation support the conclusion that the long-term survival of elderly OTR patients is largely determined by host factors versus injury variables. Subjects' gender, age at the time of injury, and number of systems with preexisting dysfunction were all strongly associated with increased mortality in the five years following the traumatic event. Unfortunately, each of these variables is a largely unmodifiable characteristic, present at the time of injury, and indicative of the underlying physiologic or functional status of the host.

In a study similar to this one, Gubler et al. (1997) used Medicare data to compare discharged Washington state geriatric trauma patients with non-injured controls and found the overall, all cause relative risk for death within five years of injury was 1.7. This figure is considerably less than the 6.26 hazard ratio noted in the current investigation.

Significant differences in subjects and controls may account for this discrepancy. Subjects in Gubler's study were notably less severely injured. As in the present investigation, almost half of Gubler's patients had Injury Severity Scores of less than 9. Only 3.5% had an ISS greater than 15, yet 31% of subjects in the current investigation had severity scores that exceeded 15.

Perhaps more important are the differences between controls. Unlike this study, which matched age, race, and gender to generic U.S. Life Table norms, Gubler's group analyzed survivors matched to non-injured persons in the Medicare database. This allowed researchers to control for preexisting conditions (PECs) as determined by Charlson Comorbidity Index (CCI) scores. Of the variables associated with early demise, Gubler found PECs to be by far the most predictive. Subjects with CCI scores of 1-3, 4-6, 7-9, and 10-13 had relative risks for death within five years of injury of 2.0, 3.6, 5.6, and 8.4 respectively.

McGwin et al. (2000) performed the only other published study of long-term survival following geriatric trauma, compared to population-based norms. This investigation found a five-year, all cause, hazard ratio for death of 1.5 in injured subjects compared to controls matched for age and sex. Dissimilarities between subjects and controls may also account for significant differences in reported survival between McGwin's study and the present one.

Compared to the current investigation, McGwin had only 102 subjects (vs. 3,633), 25% were male (vs. 53%), and no mechanism of injury or injury severity data were reported. However, 49% of subjects sustained femur or pelvis fractures, injuries in the elderly most commonly associated with ground level (low ISS) falls. Like Gubler et al. (1997), by matching subjects to uninjured persons in the Longitudinal Study of Aging database, McGwin's group were able to enter pre-injury health status as a covariate in their regression model. In contrast to non-injured controls, the injured cohort was more likely to report being in fair-to-poor health, they experienced a higher prevalence of coronary heart disease, and a greater number of pre-injury falls.

McGwin's hazard ratio of 1.5 is not dissimilar to Gubler's relative risk of death of 1.7, but both are markedly different from the hazard ratio of 6.26 documented in the present investigation. Although there are differences between subjects, the most important difference among the three studies is the control groups used. Gubler's and McGwin's controls consisted of actual persons, with documented preexisting conditions.

The present investigation uncovered a strong association between PECs and fiveyear mortality but, by comparing subjects to actuarial norms, the effect of PECs on fiveyear mortality could not be isolated. Although this difference in methodology precludes direct comparisons between Gubler's, McGwin's, and the present study, it serves to highlight the important association between pre-injury host status and the long-term survival of elderly trauma patients, and also suggests avenues for future research.

The vital role of host factors at the time of injury is further supported by the high five-year post fall mortality of subjects in this investigation. Although the majority of falls are low energy events, the hazard ratio for death within five years was 1.88 compared to subjects injured in motor vehicle collisions, a mechanism of injury frequently associated with a high amount of energy transfer. These data suggest that *who* falls may have far more to do with long-term survival than the fall itself.

# Injury and host status.

Interestingly, although Injury Severity Scores (ISS) have been shown to be an excellent predictor of in-hospital mortality following trauma (Broos et al., 1993; Frutiger, 1997; Tornetta et al., 1999), ISS had no relationship to the long-term survival of elderly subjects in this study. Gubler et al. (1997) noted a relationship between five-year survival and ISS, but it was small except in patients with an ISS above 25 (n = 64). Even then, the increase in mortality was limited to the first post-discharge month suggesting, perhaps, that many of these patients were simply moved out of a trauma center to die.

In the current investigation, the only injury variable that significantly predicted five-year vital status was Location of Injury Occurrence, yet this variable appears to be a surrogate for underlying host factors. Compared to patients whose location of injury was Roadways (the most neutral location), persons wounded in a Residential Institution (presumably frail individuals) were three times as likely to die within the study period, suggesting that preexisting patient status, and not the injury itself, was likely responsible for the three-fold increase in mortality. In contrast to persons injured in a Residential Institution, those traumatized at a Farming/Logging/Industrial site (presumably robust seniors) experienced a death rate half that of those injured on a Roadway.

Although subject to errors of interpretation, narrative text describing patients' injuries supports the argument that many elderly trauma patients were distinctly different from same age persons in the general population prior to their hospitalization. For example, descriptions of injuries sustained in a residential facility include: "fell while getting out of chair", "patient being wheeled into shower, fell off wheelchair and hit head", and "using walker to ambulate, fell over". In each of these examples, the mechanism of injury and the amount of force involved were minor, yet the long-term consequences to frail patients often proved devastating.

Conversely, narrative text for subjects injured while involved in farming, logging, or industrial pursuits paints a distinctly different picture of patients' overall level of preinjury health. Examples of trauma that occurred in this group of subjects include: "pushed over and stomped on by cow"; "hit by boulder"; "tractor rollover while raking hay"; and "3000 pound log rolled on patient". Despite the severe mechanisms of injury and the great forces involved, these narratives suggest that subjects were fairly healthy and vigorous at the time of the injury event. Therefore, the variable Location of Injury Occurrence appears to function largely as a marker of preexistent host status, rather than a unique predictor of five-year survival.

### Post-injury host status.

Likewise, the two post-injury variables that predicted long-term survival reflected subjects' functional status at the time of trauma center discharge. Discharge Limitations Score and Discharge Disposition both predicted five-year vital status. Discharge Limitations Scores served as a direct measure of functional status, but Discharge Disposition, like Location of Injury Occurrence, appears to be a surrogate for frailty. Not surprisingly, subjects who required extended post-discharge care in a skilled nursing facility or another acute care hospital were far less likely to be alive five years after injury than were those who could be discharged directly home.

## Implications for practice and policy.

These findings have important implications for geriatric trauma care. Of the three measured pre-injury variables associated with long-term survival—gender, age at the time of injury, and number of preexisting system dysfunctions—only the latter is potentially modifiable. It appears that patients with the healthiest pre-injury status have the best prognosis for long-term survival. Therefore, helping seniors maintain a generally healthy state and limiting their number of PECs may be an effective way to improve post-injury survival. Nevertheless, normal age-associated changes, on top of a lifetime of unhealthy behaviors, limit the practicality of this approach.

A more obvious and more immediate solution to the life-shortening effects of trauma in the elderly population is to prevent injury occurrence. Great strides have been made in reducing both the incidence and extent of injury in younger subjects (Hannan et al., 2004). Not only have seniors been less frequently targeted for injury prevention interventions, their risk factors are also less modifiable. Children, adolescents, and younger adults are commonly wounded while participating in high risk activities. These behaviors can be modified with protective equipment, education, and legislation.

Older adults, on the other hand, tend to experience trauma in the course of routine life events. It is possible to wear knee pads while skating, learn safer rock climbing techniques, or legislate against drunk driving. However, rising from a chair, crossing a street, and driving to the grocery store are everyday occurrences in the lives of seniors. Protective equipment, education, and safety legislation have much less impact on activities of daily living, particularly in persons with reaction time, balance, sensory, judgment, or memory impairment. Are there activities, training, or other interventions that can be used to improve or slow the loss of these vital abilities? Rich areas for future study include investigating the role of tai-chi, video games, weigh training, mental stimulation, etc. on geriatric injury reduction.

Finding ways to lower the incidence of trauma in older adults will require concerted efforts to change both clinical practice and public policy. Efforts to minimize injury in seniors must be specific to the target population, and will doubtlessly vary from strategies employed in younger age groups. In the young, individual behavior modification is the most successful approach to trauma reduction (Hannan et al., 2004; Hoskin, 2000). In the elderly, design, engineering, and community level changes have more impact on injury occurrence (Shinoda-Tagawa & Clark, 2003).

For example, helmet promotion among snowboarders may do little to lessen the incidence of injury in seniors, but passive protective equipment such as automobile air bags or hip protectors can moderate the extent of geriatric trauma (Bauza, Lamorte, Burke, & Hirsch, 2008; Levy, Hawkes, & Rossie, 2007). Sports and gun safety education may have minimal impact on older adults, but educational efforts targeted at fall prevention, burn avoidance, or senior driving safety can reduce the number of injuries (Brucher, Szczerba, & Curtin, 2007; Hoskin, 2000; MacCulloch, Gardner, & Bonner, 2007; Soreide et al., 2007; Thompson & Bourbonniere, 2006). Enforcing speed limits and imposing stiff penalties for reckless driving may not have a significant effect on geriatric trauma reduction, but reprograming light times at crosswalks, adding left turn lights to intersections, or mandating more frequent or comprehensive driving tests are examples of

legislative and engineering changes that could impact the number of injuries in the elderly (Caird et al., 2005; Lee & Abdel-Aty, 2005). With the wave of baby boomers rapidly approaching senior citizen status, community-wide injury prevention efforts, specifically tailored to the older population, need to be identified and implemented now in order to significantly minimizing the frequency and severity of geriatric trauma.

Besides promoting general health and conditioning (a pre-injury variable) and reducing the incidence of traumatic events (an injury variable), approaches must also be identified to target post-injury variables amenable to interventions. Patients' Discharge Limitations Score at the time of trauma center discharge proved to be an important predictor of five-year survival, which begs the question of whether this variable can be modified. In the present study, no data were available regarding in-hospital or in-home rehabilitation services. However, only 8.4% of subjects were discharged from a trauma center to formal rehabilitative care. Specific comparison data for the study years are not available, but the 2004-2005 Biennial Report of the Oregon Trauma Registry indicates that 4.2% of Oregon Trauma System patients (all ages) were discharged to a rehabilitation center (Oregon Emergency Medical Services and Trauma Systems, 2006). Thus, although the rehab center admission rate of seniors seems low, the elderly actually appear to be over represented in the group of OTR patients discharged to rehabilitative center care.

These numbers raise several questions. Can rehabilitative care post-injury improve functional status sufficiently to increase long-term geriatric post-injury survival? Which patients were selected for rehabilitation center placement and what survival or
quality of life gains did these individuals make as a result of the experience? Could rehabilitation centers modify their admission requirements and therapy programs to better accommodate the needs of injured seniors? And, is home or outpatient rehabilitation therapy as effective for seniors as inpatient therapy? Such questions cannot be resolved by the present study's database but their answers could significantly impact geriatric trauma care practices.

#### Study Limitations

Unlike investigations that have examined all mortality following trauma in older adults, this study was limited to persons who survived to trauma center discharge. Because of the high incidence of pre-hospital and in-hospital trauma deaths, restricting the present study to survivors inevitably underreported geriatric fatalities within the Oregon Trauma System during the study years. However, early trauma deaths are easy to capture and have been well documented at many sites in numerous studies. The outcome of trauma on mortally wounded seniors is not hard to establish. Much more difficult to ascertain is what happens to those who actually survive to discharge, the ones our health care system pronounces "healed". This was the population of interest in the present study.

Other important limitations to this investigation include the fact that it was retrospective in nature, relied on secondary data, and was restricted to information contained in the Oregon Trauma Registry and the National Death Index (NDI). Findings from an overwhelmingly Caucasian population in a largely rural Pacific Northwest state may not be generalizable to the rest of the country. Additionally, Oregon was selected as the study site precisely because it is one of few states with a well-established, comprehensive, statewide trauma system. The location was selected to minimize confounding variables and potential biases due to local and regional variations in trauma care, but this systemwide cohesiveness does not reflect practices common throughout the United States.

Although an inclusive, statewide system reduces the potential for undertriage, it is impossible to know how many injured seniors were excluded from the OTR. The Registry has no way of tracking this number, but the problem is certainly not unique to Oregon. Most trauma studies, including those specifically designed to evaluate trauma systems, include only data for patients cared for in trauma centers and entered into trauma registries. Few jurisdictions have the capacity to include an evaluation of persons cared for at non-trauma centers (Lane et al., 2003). This remains a key weakness of current trauma programs. Devising means to capture these data and include all eligible patients in the trauma care system is an important next step in trauma system development.

In the present study, only 6 subjects (0.2%) were never seen at a Level I, II, III, or IV trauma center but were nonetheless entered into the trauma registry, as mandated by the Oregon Department of Human Services. Can this small number be interpreted to imply that the vast majority of injured elders are receiving trauma center care? Or does it simply suggest that very few patients seen outside of a designated trauma facility ever become part of the OTR database? The present study noted an overtriage rate (patients who were found to have no injuries) of 2%, a number substantially lower than the 20% or

less rate that has been recommended in order to prevent missed injuries (Phillips, Rond, Kelly, & Swartz, 1996). This low number suggests that there may have been a significant number of wounded seniors not captured by the Oregon Trauma System.

A weakness of any retrospective database is that there is usually no way to confirm the completeness of the data set, even for the individuals that it does capture. In the case of the OTR, documentation of patients' PECs appears to have been incomplete. For example, out of 3,633 elderly subjects, there were no recorded instances of preexisting immunologic, neurologic, or psychiatric disease. The absence of any subjects with these common system disorders appears improbable, especially in light of the fact that the narrative cause detail and ICD codes documented many cases of cancer, Alzheimer's disease, stroke, and suicidal behavior. Understandably, information regarding preexisting medical conditions may not be easy to obtain from acutely injured patients, nor is it the primary interest of the OTR. Therefore, data regarding PECs were probably underestimated in this study. Yet, even when presumed to be underreported, preexisting conditions proved to be a strong predictor of five-year survival.

Data regarding in-hospital complications could potentially explain many of the differences noted in long-term survival. In-hospital complications information is contained in the trauma registry and was requested in the original OTR data application, but access was denied on the grounds of provider and facility confidentiality. This, unfortunately, leaves us with an incomplete picture of each patient's in-hospital stay. Pneumonia, sepsis, shock, wound infections, delirium, falls, surgical misadventure, etc. could all have significantly impacted post-discharge survival time and yet were

unknowable in this study. However, the fact that ICU and non-ICU lengths of stay were only weakly associated with five-year survival suggests that complications, which generally extend hospital time, may have increased the number of in-hospital deaths but did not have a major impact on long-term mortality.

## Implications for Future Research

# Life Tables as a Predictor of Life Expectancy

A crucial consideration when calculating the impact of any variable on survival is comparison group selection. This study compared the survival of elderly OTR entrants with U.S. Life Table actuarial norms. However, there are no data to definitively determine whether or not these life tables accurately project the remaining life expectancy of subjects' in this study.

This raises two important areas of concern. The first is statistical. Is the lifespan of elderly Oregonians similar to U.S. Life Table projections? The Oregon State Office of Disease Prevention and Epidemiology was queried, but the Office does not construct Oregon-specific life tables comparable to those of the National Center for Health Statistics (NHCS). The NCHS was also contacted, but the Center does not publish statelevel data. It would seem possible that future researchers could prevail upon the NCHS to supply state-specific life tables, which could easily address this potential statistical limitation. Nevertheless, as currently constructed, the U.S. Life Tables are considered legal evidence and are widely employed by lawyers, insurance analysts, actuaries, pension planners, demographers, and researchers (National Center for Health Statistics, 2006b).

Another important statistical limitation to interpreting the results of this study concerns the method by which controls were derived. To determine predicted life expectancy—and then establish the difference between subjects' and controls' five-year survival—the U.S. Life Tables were used. Although helpful for summarizing the current health status of a population, there are limitations to using life tables. Life expectancy calculations depend on the criteria used to select the group. If, for example, infant mortality rates are high, then life expectancy at birth is very sensitive to the rate of death in the first few years of life, artificially lowering mean life expectancy projections for those who survive early childhood.

By using age-adjusted calculations, the U.S. Life Tables try to eliminate this bias towards underestimation. Only persons who survive to reach a given age cohort are included in analysis of how long the group is expected to continue living. For each cohort of survivors, a mean remaining life expectancy is determined. However, this technique introduces an overestimation bias. Because all persons entered in the cohort calculation (e.g., those 72-73 years) have reached a minimum age (e.g., 72 years), there are none who will die prior to this age. Yet, the upper limit of age (the longest lifespan achieved by a group member) has no theoretical limit. Therefore, when age is banded on one end (e.g., 72 years) but unrestricted on the other, the mean life expectancy (used for life table calculation) can easily be skewed upward by the presence of the longest-lived outliers.

Conversely, using U.S. Life Tables to determine hypothetical matched controls

may also underestimate subjects' lifespans. The tables use data derived from current older populations to predict the future lifespan of a younger cohort. Nevertheless, social trends, medical changes, political upheaval, natural disasters, or other forces not currently in evidence could potentially reduce or extended the actual lifespan of study subjects.

The second area of concern with using the U.S. Life Tables as actuarial norms for subjects in this study is theoretical and presents ample opportunities for future research. The implicit premise behind life tables is that the age-specific probability of dying applies to all persons within the age group. Clearly, the risk of mortality is not constant and can vary greatly by gender, race, place of residence, socioeconomic status, and a host of other factors (Anderson, 2000).

The U.S. Life Tables are constructed to compensate for only a couple of common characteristics. Gender is an easily determined variable known to significantly impact life expectancy. The effect of race, the second U.S. Life Table covariate, is more difficult to establish. U.S. Life Tables dichotomously define race as White or Black. Not only are the distinctions between these categories often blurred, other racial and ethnic groups— Asians, Native Americans, Pacific Islanders, Hispanics, etc.—are excluded from all but aggregate U.S. Life Tables. Because of the largely Caucasian composition of subjects in the present study, any biases produced by this limitation were minimal. Nevertheless, racial limitations could prove a significant weakness if the study were repeated in a more ethnically diverse locale.

But the theoretical limitation more apropos to the present investigation concerns the fact that age-specific mortality rates represent only average mortality risks, which may not accurately describe the actual risk of mortality for any specific individual or cohort. What is not taken into account in life tables is the distribution of frailty within each age group. There are always persons inherently more frail and more susceptible to dying from any particular cause, at any particular age and time. Thus, death changes the composition of a cohort by differentially removing the frail first (Anderson, 2000). Only the heartiest of each cohort survive to progress to the next age group.

## Life Trajectories

Did the injury incident knock subjects off their projected life trajectories, or were they already predisposed to shorter lifespans? It is possible that subjects in the present study comprised an overrepresentation of the frail portion of the population. If so, this further supports the hypothesis that the higher rate of death noted in the five years following injury is better explained by patients' pre-injury status than by their traumatic event. Life tables are designed to reflect mean survival and there will always be individuals on either end of the normal distribution curve. Perhaps trauma, particularly in older adults, is a condition that picks off those on the lagging tail.

Because trauma outcomes research is virtually always retrospective, the question of pre-injury life trajectory has not been prospectively nor widely addressed. In their investigations of long-term outcomes following geriatric trauma, Gubler (Gubler et al., 1997) and McGwin (McGwin et al., 2000) analyzed the effect of preexisting medical conditions. Both researchers found that the pre-injury status (comorbidities and function) of older adults involved in trauma was distinctly different from that of their control populations. By comparing groups based on items in the Charlson Comorbidity Index, Gubler et al. identified a significantly increased prevalence in 11of 12 disease conditions in subjects compared to non-injured age and gender matched controls. McGwin's group noted that, in the year pre-trauma, their injured cohort was significantly more likely to report being in fair to poor health, had 2.5 times the prevalence of coronary heart disease, and experienced twice the number of falls as did controls. Such findings strongly suggest that these older trauma patients were not on a normal life trajectory even before they were injured.

Some of the most informative data on this topic is drawn from a large Canadian study, although subjects were limited to persons less than 65 years old when injured. Over 18,000 trauma patients were matched with non-injured controls randomly assigned from the Manitoba population registry (Cameron et al., 2005b). Over the 10-year follow-up period, injured subjects experienced twice the mortality (7.2% vs 3.6%) of non-injured controls. Despite carefully matching controls to injured subjects—based on age, race, gender, and geography—it became clear that the two groups were dissimilar in many ways that preceded the traumatic incident. Injured subjects had a significantly poorer preinjury health status, more all-cause hospital admissions, increased hospital lengths of stay, more physician claims in the 12 months prior to injury, more musculoskeletal disorders, and more mental health conditions. Annual mortality rates were consistently higher for the injured group, and this effect persisted throughout the ten-year study period.

Supporting the premise that host factors are key to determining long-term survival, when Cameron et al. (2005a) used the Charlson Comorbidity Index to stratify for the presence of preexisting disease, (in the same Canadian study population) the relative increased risk of death in injured subjects compared to non-injured subjects largely disappeared. It is striking that, even in this cohort of non-senior citizens, host factors appear to be a crucial determinant of short, intermediate, and long-term posttrauma survival.

Of course, simply because injured cohorts have a markedly decreased lifespan compared to non-injured controls does not prove that the traumatic event was the cause of early demise. Nevertheless, it appears that injured seniors are both at higher risk for injury and less capable of withstanding the stressors of trauma. Many elderly trauma patients may have long been on a life trajectory considerably shorter than predicted norms. This is a subject ripe for future investigation.

## Trauma Databases

There are a few minor modifications to the patient information collected by trauma center hospitals that could greatly improve the usefulness of the database. Consistent documentation of comorbidities, functional status at discharge, and postdischarge status would help future researchers answer lingering questions.

### Documenting comorbidities.

Although the OTR proved to be an excellent source of information, there are important limitations to its usefulness for studying geriatric trauma patient outcomes. These limitations are not specific to the current study, but have important implications for future trauma system evaluation and research. Limitations largely center on data not currently contained in the Oregon Trauma Registry-nor indeed in other trauma registries—but which have implications for potential changes to the OTR and other trauma databases. Because preexisting medical conditions appear to be a strong predictor of long-term survival, better measures of PECs are needed. More complete information regarding preexisting conditions could help researchers identify specific disorders that affect long-term outcomes. This could be accomplished through the consistent application of a standardized and validated system for documenting preexisting conditions, such as the Charlson Comorbidity Index. The CCI includes 19 disease conditions weighed on the basis of their association with mortality, adjusted for age. This instrument is easy to use and could be readily incorporated into existing trauma databases. See Appendix I for a sample of an online, interactive CCI scoring tool.

Of the studies identified that focused on the impact of preexisting conditions on trauma outcomes, only Gubler et al. (1997), Gabbe et al. (2005) and Cameron et al. (2005a) employed the CCI. Other researchers relied on APACHE II data (Sacco et al., 1993; Tan et al., 2004), odds or relative risk ratios (Grossman et al., 2002; McGwin et al., 2004; J. Morris et al., 1990), or their own scoring systems (MacKenzie et al., 1989). In the present investigation, 63% of patients had at least one preexisting condition. Milzman et al. (1992) found that 40% of their trauma patients had one or more PEC by the sixth decade of life and the prevalence rose to 69% by age 75. Howevr, the current lack of standarized definitions makes it difficult to draw any comparisons between studies.

The National Trauma Data Bank (NTDB) was established in 1989 in an attempt to unify trauma patient data collection. Participation by state and local registries is voluntary and there are currently over 600 participating institutions. The NTDB Data Dictionary lists 24 pre-injury disease states or categories to be included in registry information (American College of Surgeons, 2008). However, like the OTR, conditions are scored simply as present or absent. This will, at least, provide a standardized list of comorbid conditions. But, unlike the CCI, there is no severity scoring or age adjustment, making it impossible to determine whether "prematurity" is more or less important to outcome than is "steroid use".

## Documenting functional status at discharge.

Similarly, patients' functional status at the time of discharge could be more precisely documented (and thus used for analysis and comparison with other trauma systems) by employing standardized and validated scoring tools such as the very basic Glasgow Outcome Scale (Appendix J) (King et al., 2005) or the much more detailed Functional Independence Measure (Appendix K) (Corrigan, Smith-Knapp, & Granger, 1997). Because this study found both preexisting conditions and functional limitations at the time of discharge to be important predictors of long-term outcome, identifying and employing more specific and accurate means of documenting these variables could potentially suggest ways to improve geriatric patient survival. Regrettably, the NTDB does not include any measure of patients' functional status at the time of discharge.

## Documenting post-discharge status.

Also missing from the Oregon Trauma Registry are any follow-up data. This information exceeds the current scope and mandate of the OTR, but these data clearly have implications for care, particularly in geriatric trauma patients who experience an alarmingly high post-discharge mortality. If trauma system success is measured only by the number of patients discharged alive, then not tracking long-term outcomes, particularly in the elderly, will fail to capture important data. Collecting outcome information once a patient has been discharged from a trauma center would require a substantial commitment to follow and investigate cases. Nevertheless, can the full impact of any trauma system be determined without these follow-up data?

Options include tracking only a representative sample. Fifty five percent of the geriatric patients in this investigation were treated at a Level 1 trauma facility at some point during their acute injury hospitalization. There are only two such centers in the state, both of which are located in the city of Portland. Because of their close geographical association, efforts are made to evenly distribute the patient load between the two Level 1 facilities. Therefore, each Level 1 hospital sees approximately 25% of all the geriatric trauma patients in the entire Oregon Trauma System. This would mean that a representative sample could be readily identified and tracked by a single Level I facility, a potentially feasible task. At a minimum, trauma registries could annually conduct

National Death Index matches to establish patient vital status and determine time from injury to death.

Absent from the information available in the OTR are any data regarding geriatric trauma patients' quality of life, either before or after their traumatic event. How was their quality of life impacted by trauma? How do Oregon Trauma System survivors view their lives post-injury? Given the huge amount of resources consumed by elderly trauma patients, there is interest in knowing whether such expenditures are justified by beneficial outcomes.

As the population ages and medical technology explodes, end of life and quality of life issues are becoming increasingly important to patients, family members, payors, and health care providers. Clinicians often waiver anxiously between aggressive versus palliative care measures for critically injured seniors and are troubled by questions regarding whether they are doing more harm than good (Dawson, 2008). Such quality of life and ethical questions far exceed the scope of the present study or of the Oregon Trauma Registry, but answers are required in order to fully evaluate trauma system effectiveness and optimize long-term outcomes for our injured geriatric population.

#### Potential Studies Using Currently Collected Data

Although a number of limitations to the trauma registry have been noted, combining OTR records with vital status information from the National Death Index and the Social Security Death Index produced a rich data set that could serve as a source of information for future exploration. In particular, the current investigation analyzed the data set as a whole, but there are also several potential subsets of interest. Areas for further research include examining subjects by anatomical location of injury, mechanism of injury, triage criteria and trauma center usage, and other variables of interest.

# Anatomic Location of Injury

Several researchers have investigated outcomes by anatomic location of injury. Elderly trauma patients with traumatic brain injury, in particular, have a very high rate of in-hospital mortality (Coronado et al., 2005; Flaada et al., 2007; Mosenthal et al., 2002). The incidence of adverse outcomes is even higher in anticoagulated, brain-injured seniors (Karni et al., 2001; Lavoie et al., 2004; Mina et al., 2003; Reynolds et al., 2003). Did the subgroup of head trauma patients in this data set demonstrate five-year survival differences compared to geriatric trauma patients as a whole?

Subjects in this study also experienced over 700 spine and spinal cord injuries. In older adults, the most common site of injury is C1-C2 (Thompson & Bourbonniere, 2006) with potentially devastating neurologic effects. Various researchers have documented that, unlike younger populations, serious spinal cord injuries in the elderly are frequently associated with low velocity mechanisms such as ground level falls (Kannus et al., 2000; Krassioukov, Furlan, & Fehlings, 2003; Spivak et al., 1994). How did the five-year hazard for death in elderly paraplegics and quadriplegics in the present data set differ from that of the entire group?

# Mechanism of Injury

There are also specific mechanism of injury subgroups that merit closer scrutiny. In the final multivariate model, Mechanism of Injury was a nonsignificant predictor of 5year mortality. However, in bivariate analysis, patients injured in a fall had 1.88 times the risk of death within five years compared to subjects injured in a motor vehicle collision. Because fall patients comprised 33% of all subjects, and fall height greatly impacts the amount of force transmitted to the tissues, an analysis of fall patients by height of fall could potentially provide more specific prognostic information about this large group of elderly trauma survivors. The majority of falls were at ground level, but there were a substantial number of patients whose narrative detail field described "fall from a ladder", "fall down stairs", "fall from a roof", and "fall from a horse". Additionally, several subjects fell from significant heights such as "fell from fourth floor window", "fell 35 feet from a cliff into river", "fell 70-80 feet from deck", and "stumbled, fell 100 feet head-over-heels onto boulders".

As dramatic as high-level falls are, the severity of injuries associated with "simple" ground level falls is startling. Seniors in this study who experienced ground level falls often suffered subdural hematomas, subarachnoid hemorrhages, C-2 fractures, hip fractures, skull fractures, coma, rib fractures, and serious facial injuries. The relationship between fall height, preexisting medical conditions, injuries sustained, and five-year vital status merits further investigation.

Also notable in this study was the number of pedestrians and bicyclists struck by automobiles (8%), many by large vehicles at moderate-to-high rates of speed. Is there

anything different about this subset? Did long-term survival vary, compared to the entire subject group? New approaches, such as trauma geocoding (the use of computerized mapping software) can be used to pinpoint high risk intersections or other frequent sites of pedestrian injury, which could suggest interventions to minimize future incidents.

Although patients with penetrating trauma represented less than three percent of the total sample, 46 of 93 penetrating events (49%) involved intentionally self-inflicted wounds. Older adults have the highest suicide rate of any age group, and seniors account for nearly 20% of U.S. suicides (Thompson & Bourbonniere, 2006). What are the demographic and injury characteristics of this subset? Was their five-year mortality greater than that of the rest of the study population, and how often was suicide the eventual cause of death? In addition to descriptive information available from the registry, interviewing these penetrating trauma survivors could potentially provide a rich source of qualitative data regarding seniors, depression, and suicide.

#### Triage Criteria and Trauma Center Usage

Ideally, trauma triage criteria would be 100% sensitive and 100% specific but many researchers have noted the difficulty of accurately triaging injured elders to an appropriate level of care, resulting in a marked undertriage rate (Lane et al., 2003; Phillips et al., 1996; Zimmer-Gembeck et al., 1995). Less severe mechanisms of injury, differences in tissue tolerance to force, and inhibited compensatory responses to trauma combine to limit the ability of pre-hospital and non-trauma center personnel to recognize severe injury in older adults (Lane et al., 2003). The Oregon Trauma System is composed of four levels of trauma care facilities. Tertiary (Level 1) trauma centers that see a high volume of patients have documented outcomes superior to those of low volume or non-trauma centers for both geriatric and non-geriatric patients (MacKenzie et al., 2006; Meldon et al., 2002; Scheetz, 2004, 2005a, 2005b; Sugimoto, Aruga, Hirata, & Shindo, 1999). Over half (55%) of the patients in this study were seen at a Level 1 facility at some time during their hospital stay. Nevertheless, it is neither practical nor desirable to triage all injured elders to a Level 1 center. Beyond the question of appropriate resource utilization is the important issue of removing seniors from their communities and support systems. By sending 55% of subjects to a top tier trauma facility are older adults actually being overtriaging to Level 1 centers? Oregon is a largely rural state and the only Level 1 trauma hospitals lie within the Portland metropolitan area. Patients in these facilities can receive advanced care but may be separated by hundreds of miles from home and family.

Many Oregon seniors are actively engaged in ranching and farming, activities than cannot be readily halted to allow for prolonged hospital visitation in a city far from home. Therefore, the social, financial, and emotional costs of removing injured elders from their communities must also be considered when determining what level of care is most appropriate. Patients for whom death is likely may well prefer to remain in their own communities rather than be transported far from home and loved ones.

Subjects' trauma triage criteria were included in the data set received from the OTR but the information was not used in the present study. How older adults get selected for trauma system entry, what level of care they receive, and the larger issue of what level of care they actually want are all important issues to consider as the health care system seeks to optimize trauma care delivery to our senior population. These questions deserve close scrutiny by future researchers.

# Other Subpopulations of Interest

## Frail versus robust patients.

Findings from the current investigation suggest that five-year survival following geriatric trauma is largely determined by host factors, and that even the predictor variables Location of Injury Occurrence and Discharge Disposition appear to be surrogates for host status. Therefore, what can be learned from studying both the frailest and the most robust patient subgroups? It is not surprising that frail, elders experience early post-injury demise, but was the life expectancy of robust seniors significantly impacted by their acute injury event? What was the 5-year mortality of this healthiest of subgroups? Unfortunately, the current data set contains no direct measures of pre-injury health status. Frailty or robustness could possibly be inferred by combining information regarding preexisting medical conditions, location of injury, discharge location, and the narrative description of injury mechanism. However, the validity of the findings would be doubtful and the question may be better addressed using other data sources.

## Early post-discharge demise.

Another area for potential investigation is the subset of subjects who died in the first month (n = 160, 4.4%) or year (n = 543, 15%) after trauma center discharge. Was

their demise a direct result of injuries or were their injuries largely a marker of their antecedent health status? Did this subset have more preexisting medical conditions, more pre-injury functional limitations, or more in-hospital complications than the population in general? What were their most common causes of death? And, although it was nonsignificant when the total sample was analyzed, is ISS a significant predictor of early demise (within the first month or year) in this subset?

## Cause of death.

Cause of death among OTR subjects is another area that could benefit from investigation. Primary cause of death was included in the National Death Index information received from the National Center for Health Statistics, but it was not analyzed in the present study. Cause of death information was available for 93% of the 1,604 subjects who died within five years of injury. Of this number, only 153 deaths (9.5%) were attributed to traumatic injury versus a medical cause. In a study limited to Oregon trauma patients (all ages) who died within 30 days of hospital discharge, only 67% of death certificates recorded injury as the reason for patients' demise (Mullins, Mann, Hedges, Worrall, Helfand et al., 1998). In older subjects, over a greater time span, how does this proportion differ?

When trauma was recorded as the primary cause of death, was it a sequela of the index event or the result of a subsequent injury? Were there differences in the timeframe from index injury to death in persons in whom cause of death was trauma, versus those whose cause of death was a medical condition? Do elderly trauma survivors die for the

same reasons and in the same proportions as non-injured Oregonians, or is the distribution of causes significantly different?

# Trauma system trends.

An intriguing finding of this investigation was that, over the course of the study (1992-2000), the percent of elderly survivors alive five years after injury steadily declined (Table 4-8). The Oregon Trauma System was specifically designed to reduce morbidity and mortality following injury, and there is ample data to support its ability to reduce in-hospital mortality (Mann et al., 1999; Mullins & Mann, 1999). Why then were five-year survival gains not apparent among subjects in the current study? Is it simply a reflection of the rising mean group age? Are improvements in trauma care saving more injured seniors in the short run, but not benefiting their long-term survival? Or, as some studies have suggested, (Mann et al., 2001; O'Hara et al., 1996) has the number of trauma "survivors" been artificially increased because the trend toward early discharge has simply shifted the location of death from in-hospital to out of hospital settings?

## Trauma recidivists.

Lastly, there were two small but intriguing subsets of patients that warrant future investigation. First, the trauma recidivists. Gubler (1996) and McGwin (2001) both followed cohorts of discharged elderly trauma patients for a period of five years and compared their trauma readmission rates to the five-year trauma admission rates of matched controls. These researchers identified relative risks for a second injury that were 2.12 (Gubler, 95% CI, 2.01-2.25) and 3.25 (McGwin, 95% CI, 1.99-5.31) times greater than the injury incidence in controls during the same time period.

In the initial records received from the OTR, there were 27 subjects who appeared in the database twice, for separate injury events, and one who even appeared a third time. In the present study only the initial hospitalization record was used and data on repeaters were not tracked. Yet, are there pre-injury, injury, or post-injury characteristics recidivists have in common? What is the temporal relationship between injury events? These data could help identify the most at-risk individuals. However, because only survivors were included in the data set for this investigation, information regarding prehospital and in-hospital trauma deaths would also need to be examined in order to identify all recidivist cases.

### *Couple dyads.*

A second small but intriguing subset of interest involves patient dyads. In the OTR data set there were 226 individual records of persons who appear to be married couples conjointly involved in a traumatic event, in which both partners survived to hospital discharge. This figure likely underestimates the actual number of injured couples because persons who died at the scene or in hospital were excluded from analysis in this study. A marital relationship was inferred when male and female patients of a similar age, who had the same last name, were injured in the same location, in the same manner, on the same date. Virtually all instances involved motor vehicle collisions.

Because spouses commonly serve as each other's primary social and caregiving

support system, what happens when both partners are simultaneously injured? Do these pairs fair better or worse than non-couple patients? Additionally, several narrative notes included reference to a husband or wife that died at the scene of injury. How do survivors cope with their own recovery when it is complicated by acute grief for the loss of one's spouse and caregiver? Interviews with subjects whose partners either survived or died as a result of the shared injury event could add an important couples perspective to the impact of trauma on geriatric patients' long-term survival, function, and quality of life.

### Summary

Trauma is currently the seventh leading cause of death among older adults and this age group accounts for 25%-30% of all trauma care expenditures. The geriatric population is expanding rapidly and their impact on trauma centers is being felt throughout the nation. However, after 40 years of organized trauma care there is still no standarized definition of what constitutes significant trauma in this population, nor is there even a universally recognized definition of who the geriatric trauma patient is. Persons classified as "elderly" comprise an extremely heterogeneous group in terms of age, which differed between subjects in the present study by as much as almost 40 years. Perhaps even more importantly, as suggested by the findings of this investigation, seniors are extremely heterogeneous in terms of physiologic status. A great deal remains to be learned about the impact of physiology and function on trauma incidence, recovery, and long-term survival.

As is true in so many areas of research, the easy questions have been answered.

We know how many older adults are injured, how they get injured, and the type of injures they sustain. We know that in-hospital mortality for senior trauma patients is two to six times greater than that of comparably injured younger adults. But we know this information because these data have long been tracked in our trauma registries.

Much more difficult questions remain to be answered but, in order to move the field forward, researchers will need to look for ways to expand our existing data sources in order to address such important issues as: what impact does pre-injury physiologic or functional status have on post-injury outcomes? What can we do to reduce the incidence of injury in the elderly or mitigate its effects? What characteristics or interventions significantly influence trauma recovery in the elderly? And, what impact do injury and trauma care have on seniors' quality of life? Answers to these questions can be known, but will require going well beyond the trauma registry databases currently available.

The design of the present study called for merging two databases, the Oregon Trauma Registry and the National Death Index, with U.S. Life Table data in order to derive information not available in the existing registry. The goal of the study was to quantify the ongoing excess mortality burden experienced by geriatric trauma patients, to demonstrate that the relationship between injury and shortened lifespan continues well beyond the traumatic event, and to identify variables associated with post-injury life expectancy. Long-term outcome data are essential for evaluating the lasting impact of our trauma interventions. Replication of this study at individual trauma facilities, in statewide trauma systems, and with multi-regional databases—such as the National Trauma Data Bank or Medicare files—could serve to establish benchmarks against which future performance could be measured.

Importantly, this investigation does not prove that geriatric trauma shortened lifespan and, indeed, other plausible explanations or contributing factors are proposed to explain the reduced life expectancy noted in research subjects. However, this study establishes a methodology for examining the long-term impact of injury in the population of geriatric trauma survivors and provides baseline data useful for future comparison.

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Appendix A—Oregon Trauma System Hospitals

# **Oregon Trauma System Hospitals**



# Revrised: 3/13/06

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- Level I
- Legacy Emanuel Hospital & Health Center, Portland Oregon Health & Science University, Portland

# Level II

- Good Samaritan Regional Medical Ctr., Corvallis
- Sacred Heart Medical Center, Eugene St. Alphonsus Regional Medical Center, Boise, ID \* St. Charles Medical Center, Bend
- SW Washington Medical Center, Vancouver, WA \*

# Level III

- ø
- Bay Area Hospital, Coos Bay Columbia Memorial Hospital, Astoria Good Shepherd Medical Center, Hermiston 0
- McKenzie-Willamette Hospital, Springfield
  - Mercy Medical Center, Roseburg
  - Merle West Medical Center, Klamath Falls
    - Mid-Columbia Medical Center, The Dalles
- Providence Hood River Hospital, Hood River Providence Medford Medical Center, Medford

  - Rogue Valley Medical Center, Medford Salem Hospital, Salem Samaritan Albany General Hospital, Albany
- Samaritan Lebanon Community Hoppital, Lebanon St. Amfiony Hospital, Pendleton St. John Medical Centet, Longview, WA \* St. John Medical Centet, Uargview, WA \* Tillamook County General Hospital, Tillamook
- Walla Walla General Hospital, Walla Walla, WA \* Willamette Valley Medical Center, McMinnville

# Level IV

- Ashland Community Hospital, Ashland Blue Mountain Hospital, John Day
- Coquille Valley Hospital, Coquille 23. 29. 30.
- Curry General Hospital, Gold Beach Grande Ronde Hospital, La Grande
  - Hamey District Hospital, Burns 32.
- Holy Rosary Medical Center, Ontario Lake District Hospital, Lakeview
- Lower Umpqua Hospital, Reedsport Mountain View Hospital, Madras
- - Peace Harbor Hospital, Florence
- Pioneer Memorial Hospital, Heppner Pioneer Memorial Hospital, Prineville

- Providence Newberg Hospital, Newberg Samaritan North Lincoln Hospital, Lincoln City Samaritan Pacific Communities Hospital, Newport

  - - Santiam Memorial Hospital, Stayton
      - Silverton Hospital, Silverton
      - St. Charles Medical Center, Redm
- St. Elizabeth Health Services, Baker City
- Sutter Coast Hospital, Crescent City, CA
- Three Rivers Community Hospital, Grants Pass Wallowa Memorial Hospital, Enterprise West Valley Hospital, Dallas

Appendix B— Oregon Trauma Registry Data Collection Instrument

Oregon Trauma Registry Data Collection Instrument, Page 1

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Oregon Trauma Registry Data Collection Instrument, Page 2

ED DATA			Useritel	A	Darka i	,	,		UBBAGO	*Airway Options
Clinical Data: Num <u>Field 1</u> ED (Admit) 2	Resp* Rate	Pulse Rate	SBP	Eye	Verbal	Motor	GCS	Airway*	End Tidal CO <sub>2</sub> *	Normal         PEAD           Oral/Nasal         CRIC           P- Trach         TRACH           P- BVM         BVM           P- ET         ET tube           LMA         LMA
ED (1 hour/Last) 3										* End Tidal CO <sub>2</sub> Options
	*Unassiste	d								Yes Not Applicable <u>NOT</u> Available
Provider Times in ED: ( <u>T</u> rauma <u>S</u> urgeon	Call Time :		Arrival Tir	me		ANESthe	esiologist	Call T	ime :	Arrival Time
NEUROsurgeon	:		:			ED MD			:	:
Resuscitation: Procedures: Diagnostics:	NONE	<u>BLOOD</u> <u>CT H</u> ead	<u>CHES1</u> I/neck <u>C1</u>	<u>r</u> tube <u>r C</u> hest	<u>CPR</u> <u>CT A</u> bo	DPL I/pelvis	FAST ANGIO	<u>THORA</u> <u>H</u> ead/nec	otomy/Pericar	diocentesis <u>ART</u> I line <u>SG</u> /CVI <u>C</u> hest <u>ANGIO-P</u> elvis/extremities
ED Disposition: (INPT)	OR I DisCharr	ICU <u>FL</u>	LOOR [ XPired	DIRECT	OTHE DOA	<u> R</u>	TRAN	Sfer	(specify)	(specify)
ED Discharge/Death Time:	<u>oiso</u> naig :		ED Disc	harge/De	eath Date	<u>.</u>	/ /	<u></u>	(MM/DD/YY	)
INPATIENT DA	TA			-					-	и 
npt. Admit Date: /	/	(	MM/DD/YY	)						
Admit Service (circle only on	e): Traum Detail	a/ <u>GEN</u> era (optional)	ISurg <u>OF</u>	RTHOpe	dic <u>NEU</u>	IROsurg	OMFS	THOR	OTHER surg	PEDS NON-surg
Consults (circle all that apply	/): Traum <u>NONE</u>	a/ <u>GEN</u> eral	Surg <u>OF</u>	RTHOpeo	lic <u>NEU</u>	RO <sub>surg</sub>	<u>OMFS</u>	THOR	OTHER surg	PEDS NON-surg
DR Procedure Data:	C+-	art Time	Start	Data			de	MD	Start Tim	o Start Data
		:	/	/		1000 00			:	
		:		1						<u> </u>
Fotal ICU Days		:	/	/					:	/
Medical History (circle all tha NEUROlogical PSYCHi	itapply): atric <u>IM</u>	<u>NONE</u> <u>M-D</u> isease	CARDiova IMM-	scular <u>T</u> herapy	<u>RESP</u> irat <u>IMM-F</u>	ory Ant ost-spier	i- <u>COAG</u> N ectomy	Medication <u>UNK</u>	LIVER R	ENAL <u>DIAB</u> etes <u>PREG</u> nancy (specify)
npatient Discharge Dispositi Facility I	ion: <u>HOI</u> Name	ME HO	D <u>ME-H</u> ealth	FO of:	<u>STER</u> Car REHAB	e <u>ASS</u> ACUTI	<u>BIST</u> ed Li <sup>,</sup> E care	ving <u>S</u> or OT	<u>NF</u> -ICF <u>A</u> HER facility	MA EXPired
npt. Discharge/Death Time:	:		Inpt. Disch	harge/De	ath Date		/		(MM/DD/YY)	Advanced Directive
Functional Ability: Pre-Injury disability (cire Post-Injury Functional (	cle one eac Status at Di	h): Loco	omotion:	<u>Y</u> es	<u>N</u> o	Commu	nication:	<u>Y</u> es	<u>N</u> o	Support Withdrawn
Feeding	IND		MOD/IND		MOD/DE	<u>P</u>	DEPEN	<u>□</u>	PED	<u>Y</u> es <u>No NA</u>
Locomotion Communication						_				Discharge GCS
DIAGNOSIS										
ICD9 Code	_		1	Narrative				A	IS	Body Region
	_									
	_									
	_									ISS
Donation Status: <u>TISS</u> ues		<u>G</u> ans	BOTH	NOI	NE	NA		Autop	sy: <u>Y</u> es	<u>No NA</u>

Oregon Trauma Registry Data Collection Instrument, Page 3

COMPLICATIONS	LAST, FIRST NAME	
Mark all that apply and note corresponding	ICD-9 code in section below:	
Hospital - Pulmonary:	IV. Hospital - Hepatic, Pancreatic, Biliary, Splenic:	IX. Hospital - Neurologic:
Adult respiratory distress syndrome/ <u>ARDS</u> <u>Adult respiratory distress syndrome/ARDS</u> <u>EMPY</u> ema     FAT embolus <u>IEMQThorax</u> <u>PNEUMQthorax</u> <u>Pulmonary Embolus</u> <u>Hospital - Cardiovascular</u> <u>Myocardial Infarction/MI</u>	V. <u>Hospital - Hematologic:</u> COAGulopathy Disseminated intravascular coagulation/ <u>DIC</u> VI. <u>Hospital - Infection</u> FUNGAL sepsis Intra-ABDominal abscess SEPSIS-like syndrome Dispersia	Diabetes inspectos     MENingitis     SElZure in hospital     SELZURE in hospital     SIADH     VENTRiculitis-     postsurgical      X. Hospital - Vascular:     ANAStomotic hemorrhage     Diaean Venous Thromhosis
Pericardial <u>EFFUS</u> ion or tamponade <u>SHOCK</u>	SINUSitis     Wound INFECTion	GRAFT infection
Hospital - Gastronintestinal (GI): Anastamotic <u>LEAK</u> DEHIScence/evisceration <u>ENTER</u> otomy-iatrogenic <u>FIST</u> ulas HEMORRhage <u>PERI</u> tonitis <u>Small Bowel O</u> bstruction	VII. Hospital - Renal/Genitourinary (GU):         Renal Failure         Urinary Iract Infection         VIII.Hospital - Musculoskkeletal/Integumentary:         COMPartment syndrome         Decubitus (OPEN sore)         Decubitus (DEEP)         OSTEOmyelitis	XI. <u>Other:</u>
ICD9 Code	Narrative AIS	Body Region
Mark all that apply: <u>Prehospital - Airway:</u> <u>SOPH</u> ageal intubation <u>Prehospital - Miscellaneous:</u>	IV. <u>Hospital - Miscellanec</u> ANESthetic complical <u>HYPO</u> thermia <u>DOTOPerative herr</u> NON-OPerative mana <u>SBP</u> <70 mmHg more	us: ion orrhage urgery <48 hrs. of first surgery gement of abdominal GSW than one hr. after ED admission
<ul> <li>No <u>EMS</u> form</li> <li><u>INTUB</u>ation required 5-10 min. after patient</li> <li><u>MUL</u>Tiple patient scene</li> <li><u>MOLTIPLE Provider errors/delays:</u></li> <li><u>DELAY</u> or failure to activate the trauma tean</li> <li><u>Delay/EROR</u> in diagnosis</li> <li><u>Intracranial injury W/LOC, CAT scan &gt;2 hour</u></li> </ul>	V. <u>Other:</u> D <u>NONE</u>	
No <u>EMS</u> form <u>INTUBation required 5-10 min. after patient</u> <u>MUL</u> Tiple patient scene <u>Hospital - Provider errors/delays:</u> <u>DELAY</u> or failure to activate the trauma tean     Delay/ <u>ERROR</u> in diagnosis     Intracranial injury w/LOC, <u>CAT</u> scan >2 hour	V. <u>Other:</u> n <u>NONE</u> s	
No <u>EMS</u> form <u>INTUB</u> ation required 5-10 min. after patient . <u>MUL</u> Tiple patient scene <u>Hospital - Provider errors/delays:</u> <u>DELAY</u> or failure to activate the trauma tean <u>Delay/ERROR</u> in diagnosis     Intracranial injury w/LOC, <u>CAT</u> scan >2 hour     COMMENTS:	V. <u>Other:</u> n D <u>NONE</u> s	

Appendix C-Oregon Health & Science University (OHSU) IRB Approval

### **OHSU IRB Process Details**

Prior to either OHSU or Oregon Department of Human Services Institutional Review Board approval, a preliminary request was sent to the Oregon Trauma Registry to inquire about the potential number of qualifying subjects. This exploratory request was made in order to establish an approximate number of subjects to determine if the study would have sufficient power. The OTR reported 4,114 qualifying subjects and this was the number submitted in the initial OHSU IRB request. (See: Initial OHSU Institutional Review Board Approval form.) When the data were actually received, there were 4,572 records representing 4,174 patients. However, only 4,162 index hospitalization records had sufficient basic information to be examined further. Twelve records were missing key information such as date of injury. The final number of study subjects was only 3,633.

Acting on the suggestion of National Death Index personnel, a modification request was sent to the IRB to include the records of ten known-dead subjects for each study year to serve as a check to determine how well the NDI was able to identify OTR patients. (See: Representation Form for Research Involving Only Decedents' Information.) This modification was approved and the names of 90 known-dead OTR subjects were submitted to the NDI, along with all other names, but these individuals were not included in any further counts or analyses. (See: OHSU IRB Modification Request Approval Communication.)

# Initial OHSU Institutional Review Board Approval, Page 1

ORECO	N HEALTH & SCIENCE UNIVERSITY
Research 2525 SW Phone: (5	Integrity Office, L106-RI First Avenue, Portland, OR 97201 503) 494-7887
Date:	August 31, 2006
То:	Deborah Eldredge, PhD
From:	Susan B. Bankowski, MS, JD, Chair, Institutional Review Board, L106-RI Gary T. Chiodo, DMD, FACD, Director, OHSU Research Integrity Office, L106-R Charlotte Shupert, Ph.D., Associate Director, Research Integrity Office, L106-RI Kara Manning Drolet, Ph.D., IRB Co-Chair, Institutional Review Board, L106-RI Susan Hickman, Ph.D., IRB Co-Chair, Institutional Review Board, L106-RI Katie McClure, M.D., IRB Co-Chair, Institutional Review Board, L106-RI
Subject:	IRB00002890, 5-Year Survival Following Injury in Geriatric Patients
	Initial Study Review
This mem ICH-GCP Procedur This stud Your pro reviewed	Protocol Approval no also serves as confirmation that the OHSU IRB (FWA00000161) is in compliance with codes 3.1-3.4 which outline: Responsibilities, Composition, Functions, and Operations, es, and Records of the IRB. y is approved for 4,114 record sets. Dotocol (DHHS Grant Application for Funding Period 09/01/06 - 08/31/07) was by the full board and approved for one year effective 08/24/2006.
This mem ICH-GCP Procedure This stud Your pro- reviewed Other ite Protocol 3 Trauma F Other ite Review R	Protocol Approval no also serves as confirmation that the OHSU IRB (FWA00000161) is in compliance with codes 3.1-3.4 which outline: Responsibilities, Composition, Functions, and Operations, es, and Records of the IRB. y is approved for 4,114 record sets. totocol (DHHS Grant Application for Funding Period 09/01/06 - 08/31/07) was by the full board and approved for one year effective 08/24/2006. ems reviewed and administratively approved by the IRB include: Lay Language Summary; Data Requested from the Trauma Registry; OR Trauma Registry Document Registry Abstract Form. ems reviewed and noted by the IRB include: Memo to IRB dated July 5, 2006; Initia Response dated August 30, 2006.
This mem ICH-GCP Procedure This stud Your proceeder Other ite Protocol S Trauma F Other ite Review F This stud determine	Protocol Approval no also serves as confirmation that the OHSU IRB (FWA00000161) is in compliance with codes 3.1-3.4 which outline: Responsibilities, Composition, Functions, and Operations, es, and Records of the IRB. y is approved for 4,114 record sets. notocol (DHHS Grant Application for Funding Period 09/01/06 - 08/31/07) was by the full board and approved for one year effective 08/24/2006. ems reviewed and administratively approved by the IRB include: Lay Language Summary; Data Requested from the Trauma Registry; OR Trauma Registry Document Registry Abstract Form. ems reviewed and noted by the IRB include: Memo to IRB dated July 5, 2006; Initia Response dated August 30, 2006. y now meets the criteria for EXPEDITED IRB review based on Category #9, research ed by the convened board (08/24/2006) to involve no greater than minimal risk.
This mem ICH-GCP Procedure This stud Your pro- reviewed Other ite Protocol 3 Trauma F Other ite Review R This stud determine The requi clements This men	Protocol Approval The oalso serves as confirmation that the OHSU IRB (FWA00000161) is in compliance with codes 3.1-3.4 which outline: Responsibilities, Composition, Functions, and Operations, es, and Records of the IRB. The server of the trace of the t
This mem ICH-GCP Procedury This stud Your pro- reviewed Other ite Protocol 3 Trauma F Other ite Review F This stud determine The requi- clements This men • That th	Protocol Approval The oalso serves as confirmation that the OHSU IRB (FWA00000161) is in compliance with codes 3.1-3.4 which outline: Responsibilities, Composition, Functions, and Operations, es, and Records of the IRB. The service of the transmission of transmission of the transmission of transmissin transmission of transmissin transmissin
This mem Procedure This stud Your procedure Other ite Protocol 3 Trauma F Other ite Review R This stud determine The requi clements This men • That the	Protocol Approval no also serves as confirmation that the OHSU IRB (FWA00000161) is in compliance with codes 3.1-3.4 which outline: Responsibilities, Composition, Functions, and Operations, es, and Records of the IRB. y is approved for 4,114 record sets. notocol (DHHS Grant Application for Funding Period 09/01/06 - 08/31/07) was by the full board and approved for one year effective 08/24/2006. ems reviewed and administratively approved by the IRB include: Lay Language Summary; Data Requested from the Trauma Registry; OR Trauma Registry Document Registry Abstract Form. ems reviewed and noted by the IRB include: Memo to IRB dated July 5, 2006; Initia Response dated August 30, 2006. y now meets the criteria for EXPEDITED IRB review based on Category #9, research ed by the convened board (08/24/2006) to involve no greater than minimal risk. irement to obtain informed consent and HIPAA authorization has been waived or its have been altered in accordance with 45CFR46.116(d)(1-4) and 45CFR164.512(i)(1)(i) no confirms: the research involves no more than minimal risk to the subjects;

### OHSU Institutional Review Board Approval, Page 2



<b>OHSU IRB Representation</b>	n Form for Rese	earch Involving On	ly Decedents'	Information
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INVOLVIN	ENTATION FORM FOR G ONLY DECEDENTS'	INFORMATION
This form must be completed by of deceased persons that contain examines those records.	the investigator(s) who is PHI. It must be completed	ntends to examine records/specimens ted <i>before</i> the investigator(s)
1. Name(s) of Investigator(s): Deborah Eldredge, PhD RN Laura M. Criddle MS RN	Departmen School of Nu School of Nu	nt(s) of Investigator(s): rsing rsing
2. The investigator(s) listed in #1 a for the following research purp This request for decedent information Following Injury in Geriatric Patient Trauma Registry data with National to have survived to hospital discharg subjects who are known to be dead to patients to establish the accuracy of	above intends to examines poses: ( <i>please describe</i> ) n is a small modification to the a s" (IRB 00002890). This project Death Index information to asce e. The director of the National L o our National Death Index searco our crossmatching methodology.	records/specimens of deceased persons <u>lready approved study "5-Year Survival</u> <u>is involving 4174 patients, crosslinks Oregon</u> <u>rtain 5-year mortality among persons known</u> <u>beath Index suggested that we add 90</u> <u>ch of elderly Oregon Trauma Registry</u>
<ol> <li>Please identify the source (e.g. records/specimens of deceased This modification would involve aski security numbers, and death dates of during the study years (10 records pe study. The information would serve of Index is able to identify the deaths of Index has been determined, these records</li> </ol>	, tissue specimens, databas l persons the investigator(s <u>ng the Oregon Trauma Registry</u> 90 persons known to have died a r study year). Data from these in nly as a quality check to establis subjects in our study. Once the ords will be deleted.	se, medical records) of the ) proposes to examine for this research: to supply the names, birth dates, social after entry into the Oregon Trauma System dividuals would not be included in the larger sh the extent to which the National Death rate of matching with the National Death
<ol> <li>Will the PHI be shared with an If yes, what PHI will be coded identifiers) The names, birth dates, sociative the National Death Index in the National Death Index; maginary sectors and the sectors are and the sectors and the sectors and the sectors are and the sectors and the sectors are and the sectors and the sectors are and t</li></ol>	ayone outside of OHSU? [ shared and how will it be in al security numbers, and death d order to establish a match. Thes atch information will be returne	Yes No dentified? ( <i>i.e. name of decedent</i> , ates of the 90 decedents will be shared with e data will be mailed on a computer disk to d in the same format.
[Note: If the PHI above is shar to account for the disclosu	red outside of OHSU, addit re(s).]	ional documentation may be necessary
In signing this form, the investig A. The use or disclosure of PF B. The PHI is necessary for th C. If the Institutional Review as to the death of the indiv	gator(s) represents and ag II is sought solely for resea e research purposes. Board requests it, the inves iduals.	rees to the following: irch on the PHI of decedents. tigator(s) will provide documentation
Printed Name: Deborah Eldredge	Signature:	Date:

# OHSU IRB Modification Request Approval Communication, Page 1

OREG Research 2525 SW Phone: (5	ON HEALTH & SCIENCE UNIVERSITY Integrity Office, L106-RI First Avenue, Portland, OR 97201 MEMO MEMO
Date:	04/18/2007
To:	Deborah Eldredge, PhD
From:	Susan B. Bankowski, MS, JD, Chair, Institutional Review Board, L106-RI Gary T. Chiodo, DMD, FACD, Director, OHSU Research Integrity Office, L106-RI Charlotte Shupert, PhD, Associate Director, Research Integrity Office, L106-RI Kara Manning Drolet, Ph.D., IRB Co-Chair, Institutional Review Board, L106-RI Susan Hickman, Ph.D., IRB Co-Chair, Institutional Review Board, L106-RI Katie McClure, M.D., IRB Co-Chair, Institutional Review Board, L106-RI
Subject:	IRB00002890, 5-Year Survival Following Injury in Geriatric Patients Modification ID#: MR00007412, Modification Title: 5 Year survival following geriatric traums
	Modification Request Approval Communication
* This str Your Mo approved	udy's current IRB approval lapses on $08/23/2007$ . dification Request originally submitted on $3/30/2007$ was reviewed and administrative l by the IRB on $4/19/2007$ .
* This stu Your Mo approved Items add decedent The requelements This men	udy's current IRB approval lapses on <u>08/23/2007</u> . dification Request originally submitted on 3/30/2007 was reviewed and administrative l by the IRB on <u>4/19/2007</u> . ministratively reviewed and noted include: Representation Form for Research involving s. uirement to obtain informed consent and HIPAA authorization has been waived or its have been altered in accordance with 45CFR46.116(d)(1-4) and 45CFR164.512(i)(1)(i) mo confirms:

### OHSU IRB Modification Request Approval Communication, Page 2

after participation. This waiver of consent and authorization applies only to the PHI for which use or access has been requested and described in the attached request for waiver. Accounting for disclosures is not needed because only identifiers, not PHI, will be disclosed outside of OHSU. This approval may be revoked if the investigators fail to conduct the research in accordance with the guidelines found in the Roles and Responsibilities document (<u>http://www.ohsu.edu/research/rda/rgc/randr.pdf</u>).

Appendix D-Oregon Department of Human Services IRB Approval

Oregon Department of Human Services Institutional Review Board Approval, Page 1

	PUBLIC HEALTH INSTITUTIONAL REVIEW BOARD 800 NE Oregon Street, Suite 930 Portland, OR 97232 Phone: (971) 673-1221 Fax: (971) 673-1299
	November 8, 2006
TO:	Laura Criddle OHSU, School of Nursing
FROM:	Jennifer Woodward, PhD; Vice-Chair
SUBJEC	T: IRB-06-20 Five Year Survival Following in Geriatric Patients
on geriatr accordance been colle County P the above The requi its element 164.512(i • the	The patient's five year survival, compared to each patient's projected mespan. In the with 45 CFR 46.110 (b)(1), category (F)(5) [research involving data that have exceed for non-research purposes], the DHS-Public Health Division/Multnomah ablic Health Institutional Review Board has completed an expedited review of study. This study is approved for one year effective November 7, 2006. The rement to obtain informed consent and HIPAA authorization has been waived or the altered in accordance with 45 CFR 46.116(d)(1-4) and 45 CFR )(1)(i). The IRB finds that: research involves no more than minimal risk to the subjects; waiver does not adversely affect the rights and welfare of the subjects:
<ul><li>the</li><li>the</li></ul>	research could not practicably be conducted without the waiver; research could not practicably be conducted without access to and use of the
• the	I; use or disclosure of the PHI involves no more than minimal risk to the privacy he subjects as a result of:
	> An adequate plan to protect health information identifiers from improper use
	<ul> <li>An adequate plan to protect health information identifiers from improper use and disclosure;</li> <li>An adequate plan to destroy identifiers at the earliest opportunity consistent with the research;</li> <li>Adequate written assurances that the PHI will not be reused or disclosed to any other person or entity, except as required by law, for authorized oversight of the research study or for other research for which the use or disclosure of the PHI would be permitted; and</li> </ul>

### Oregon Department of Human Services Institutional Review Board Approval, Page 2

Laura Criddle November 8, 2007 Page 2 > Whenever appropriate, the subjects will be provided with additional pertinent information after participation. Any problems of a serious nature must be brought to the immediate attention of the IRB, and any proposed changes must be submitted for IRB approval before they are implemented. The Project Revision/Amendment form and the Adverse Event Report form can be obtained by e-mailing Mellony Bernal at mellony.c.bernal@state.or.us. The IRB must review and approve all human subjects research protocols at intervals appropriate to the degree of risk, but not less than once per year. There is no grace period beyond one year from the last IRB approval date. It is ultimately your responsibility to submit your research protocol for continuation review and approval by the IRB. Please keep this approval in your protocol file as proof of IRB approval and as a reminder of the expiration date. To avoid lapses in approval of your research and the possible suspension of subject enrollment and/or termination of the protocol, please submit your continuation request at least six weeks before the protocol's expiration date. Upon completion of your study, please contact Mellony Bernal at mellony.c.bernal@state.or.us so that steps can be taken to close the study from further IRB review. Thank you for your continued diligence in the protection of human subjects. cc: Deborah Eldredge Raelene Jarvis DHS-HS FWA #00000520

Appendix E-NCHS National Death Index Approval

NCHS National Death Index Approval, Page 1



NCHS National Death Index Approval, Page 2

Page 2 – 1	Laura M. Crid	dle, Ph.D(c), RN.		
You must subpoena your use c	also contact u or court orde of the NDI.	is whenever you receiv r for any identifying in	e (or feel you might soon receive formation obtained as a result of	e) a f
Please refe submissio	er to the enclo on. Then expr	osed CHECKLIST when ress mail your records t	n preparing your records for o:	
		National Death Attn: Michelle G 3311 Toledo Roa Hyattsville, Maa (301) 458-4444	Index boodier d, Room 7318 ryland 20782	
NDI searc note that t the end of	hes can be pe the NDI files a a particular c	rformed beginning wit are updated annually, a alendar year.	n deaths occurring in 1979. Plea pproximately 11 to 15 months af	se ter
The follow searches o	/ing, more rec »r <b>NDI Plus</b> s	ent, years of death are searches:	(or will be) available for <b>routin</b>	e
Dea	th Year	Routine Searches	NDI Plus Searches	
200	9-2004 95	Available April 2007	Available April 2007	
		Sincerely you Much Robert Bilgr.	urs, elle Goodie ad. M.A. M.P.H.	
		Special Assis Division of V	itant to the Director ital Statistics	
Enclosures	3			

Appendix F—Sample National Death Index Retrieval Report



Available on the National Center for Health Statistics, National Death Index. http://www.cdc.gov/nchs/data/NDI\_Retrieval\_Back.pdf

This sample is retreived from the NDI website and does not contain actual subject data.
Appendix G—Social Security Death Index Interactive Search Form

Social Security Death Index Interactive Search Form

## Social Security Death Index Interactive Search

81,074,156 Records last updated on 2-22-2008

The most full-featured SSDI search engine on the internet

Last name		Exact	•	
First Name				
Middle Name		(initial)		
SSN				
Last Residence		Last Benefit		
Zip				
State				
County				
City				
Birth				
Year	Month	Any 💌	Day	Any 💌
Death				
Year	Month	Any 💌		
Issue Any State			•	1
Submit Clear	Simple S	earch		

Appendix H—Sample U.S. Life Table

## Sample U.S. Life Table

16 National Vital Statistics Report, Vol. 50, No. 6, March 21, 2002

Table 5. Life table for white males: United States, 1999-Con.

	Proportion dying during age interval	Number living at beginning of age interval	Number dying during age interval	Stationary population in the age interval	Stationary population in this and all subsequent age intervals	Life expectancy at beginning of age interval
Age	$q_x$	l <sub>x</sub>	d <sub>x</sub>	L <sub>x</sub>	Τ <sub>×</sub>	e <sub>x</sub>
Age           67-68           68-69           69-70           70-71           71-72           72-73           73-74           74-75           75-76           76-77           77-78           78-79           80-81           81-82           82-83           83-84           84-85           85-86           86-87           87-88           88-89           89-90           90-91           91-92           92-93           93-94	qx           0.02364           0.02598           0.03172           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03376           0.03973           0.04319           0.04682           0.05682           0.05982           0.06568           0.07270           0.08953           0.09850           0.10763           0.11793           0.12890           0.14056           0.15290           0.16594           0.17965           0.19403           0.20907	/x 76,097 74,298 70,303 68,115 65,816 63,407 60,888 58,258 55,531 52,720 49,827 46,846 43,769 40,587 37,310 33,970 30,624 27,328 24,105 20,998 18,047 15,287 12,751 10,460 8,430 6,668	a <sub>x</sub> 1,799 1,930 2,064 2,188 2,299 2,409 2,519 2,630 2,728 2,811 2,892 2,981 3,077 3,182 3,277 3,340 3,340 3,340 3,246 3,223 3,107 2,951 2,759 2,537 2,291 2,030 1,763 1,498	L <sub>x</sub> 75,197 73,333 71,336 69,209 66,966 64,612 62,148 59,573 56,895 54,125 51,273 48,337 45,308 42,178 38,949 35,640 32,297 28,976 25,716 22,551 19,522 16,667 14,019 11,605 9,445 7,549 5 919	7x 1,125,224 1,050,027 976,694 905,359 836,149 769,184 704,572 642,424 582,851 525,957 471,832 420,558 372,221 326,913 284,735 245,786 210,146 177,850 148,874 123,158 100,606 81,084 64,417 50,398 38,793 29,348 21,799	e <sub>x</sub> 14.8 14.1 13.5 12.9 12.3 11.7 11.1 10.6 10.0 9.5 9.0 8.4 8.0 7.5 7.0 6.6 6.2 5.8 5.5 5.1 4.8 4.5 4.2 4.0 3.7 3.5 3.3
94-95 95-96 96-97 97-98 98-99 99-100. 100+	0.24099 0.25781 0.27514 0.29294 0.31114 0.32969 1.00000	5,169 3,924 2,912 2,111 1,493 1,028 689	1,246 1,012 801 618 464 339 689	4,547 3,418 2,511 1,802 1,260 859 1,484	15,880 11,334 7,916 5,404 3,603 2,342 1,484	3.1 2.9 2.7 2.6 2.4 2.3 2.2

National Vital Statistics Report, National Center for Health Statistics, U.S. Life Tables, 1999. http://www.cdc.gov/nchs/products/pubs/pubd/lftbls/life

Appendix I—Sample Charlson Comorbidity Index Calculator





Appendix J—Glasgow Outcome Scale

,	-,
core	Description
1	DEATH
2	PERSISTENT VEGETATIVE STATE Patient exhibits no <i>obvious cortical</i> function.
3	SEVERE DISABILITY (Conscious but disabled). Patient depends upon others for daily support due to mental or physical disability or both.
4	MODERATE DISABILITY (Disabled but independent). Patient is independent as far as daily life is concerned. The disabilities found include varying degrees of dysphasia, hemiparesis, or ataxia, as well as intellectual and memory deficits and personality changes.
5	GOOD RECOVERY Resumption of normal activities even though there may be minor neurological or psychological deficits.
OTAL (	Resumption of normal activities even though there may be minor neurological or psychological deficits.

Appendix K—Functional Independence & Functional Assessment Measures

## Function Independence Measure & Functional Assessment Measure

FUNCTIONAL INDEPENDENCE MEASURE <sup>TM</sup> AND Brain Injury	D FUNCTIONAL ASSESS	MENT MEASURE
<ul> <li>Scale:</li> <li>7 Complete Independence (timely, safely)</li> <li>6 Modified Independence (extra time, devices)</li> <li>5 Supervision (cuing, coaxing, prompting)</li> <li>4 Minimal Assist (performs 75% or more of task)</li> <li>3 Moderate Assist (performs 50%-74% of task)</li> <li>2 Maximal Assist (performs 25% to 49% of task)</li> <li>1 Total Assist (performs less than 25% of task)</li> </ul>	BRAIN INJURY RESOURCE FOUNDATION	Brain Injury Association of Georgia
SELF CARE ITEMS	Adm Goal D/C F/U	
1. Feeding		
2. Grooming		
3. Bathing		
<ol> <li>Dressing Upper Body</li> <li>Dressing Lower Body</li> </ol>		
6. Toileting		
7. Swallowing*		
OPUDIOTER CONTROL		
SPHINCTER CONTROL		
9. Bowel Management		
o. Donei management		
MOBILITY ITEMS (Type of Transfer)	· · · · · · · · · · · · · · · · · · ·	
10. Bed, Chair, Wheelchair		
12. Tub or Shower		
13. Car Transfer*		
LOCOMOTION		
14. waiking/wheelchair (circle)		
16. Community Access*		
2		
COMMUNICATION ITEMS		
17. Comprehension-Audio/Visuai (circle)		
19. Reading*		
20. Writing*		
21. Speech Intelligibility*		
PSVCHOSOCIAL ADJUSTMENT		
22. Social Interaction		
23. Emotional Status*		
24. Adjustment to Limitations*		
25. Employability*		
COGNITIVE FUNCTION		
26. Problem Solving		
27. Memory		
28. Orientation*		
29. Attention* 30. Safety Judgement*		
55. Safety Judgement		
*FAM items		
Admt Date D/C Date Ad	fant Date D/C I	Date
RN ST		
PT PSY		
0 KEC		