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Factors Associated With Sharps Injury Rates in California Hospitals in 2001

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Factors Associated With Sharps Injury Rates in California Hospitals in 2001

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Dedication and Acknowledgements Page

This dissertation is dedicated to the healthcare workers who courageously provided care every day to patients and communities affected by AIDS. Because of their commitment to care, workers around the globe who today continue in their footsteps are perhaps a little safer, but not completely safe, from work related infections. To all who have worked for years to reduce injuries from sharps, thank you. There is new work to be done, and as Senator Edward Kennedy said: "The work goes on, the cause endures, the hope still lives, and the dream shall never die." May the dream of safe work places never die.

On a personal note, this dissertation is dedicated to my Uncle Donny. He would have loved to see this day, as he was with me at every important step of my life, whether they were good days or tough days. He was my best friend ever, and he'd love to know that Mary Ellen finally finished her PhD.

Abstract Page

Factors Associated With Sharps Injury Rates in California Hospitals in 2001

Mary E. Foley MS, RN

Among the hazards to healthcare workers are percutaneous injuries (PI) caused by devices such as needles, scalpels, and suture needles (often categorized as sharps) capable of cutting or penetrating the skin. Hospitals are the largest employer and highly technological hospital care frequently exposes workers to a variety of devices capable of causing injury. **Aims:** The objective of the study was to examine the relationship between hospital, market, and population characteristics that may be associated with sharps and needlestick injury rates in hospital-based healthcare workers in California hospitals in 2001. **Methods:** A cross-sectional secondary data analysis was performed to examine the relationships between factors which may be associated with sharps injury rates in hospital staff and nurses working in California acute care hospitals in 2001. Two analyses were performed 1) Sharps Injury Rates in All Staff (n=207) and 2) Sharps Injury Rates in Nurses (RN and LVN) (n=160). Analysis included correlations, non-parametric testing, and multiple regression. **Results:** In the all staff model, the R^2 was .412 $_{(F13, 193)}$ = 10.395; *p* = <.0005), with an adjusted R^2 for .372, indicating that approximately 41% of the variance in rate in injuries to all staff was accounted for by the combination of the independent variables. Three of the 12 independent variables (percent of discharges by Medi-Cal, Medicare, and daily hospital expenses) provided a significant, unique contribution to the model. The second analysis, Sharps Injury Rates in Nurses, had a R^2 for the overall model of .284 ($F_{10, 149}$)=5.917 ; p <.0005), with an adjusted R^2 of .236, indicating that approximately 28% of the variance in needlestick and sharps injury rates

reported in nursing staff in 2001 was accounted for by the combination of predictor variables. Two of the variables (hospitals that received greater levels of reimbursement from Third Party sources as contrasted with those that received Medicare as the major source and higher RN productive hours) provided a significant, unique contribution to the model.

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Chapter 1: Statement of the Problem

Introduction

In 1997, Dr. Bonnie Rogers, a leader in occupational health nursing, delineated five categories of safety risk hazards for healthcare workers: 1) biological/infectious risks, 2) chemical risks, 3) environmental/mechanical risks, 4) physical risks, and 5) psychosocial risks (Rogers, 1997). Healthcare workers are exposed to a range of occupational injuries and illness that include infectious diseases, workplace violence, overexertion, chemicals such as ethylene oxide and glutaraldehyde, shift work, and psycho-social stressors (National Occupational Research Agenda Healthcare and Social Assistance Sector, 2009). The healthcare sector is considered the second fastest growing sector in the United States with over twelve million employees (National Institute of Safety and Health, 2009). According to the National Institute for Occupational Safety and Health (NIOSH), rates of occupational injury to healthcare workers have risen over the past decade. This is in stark contrast to safety accomplishments in agriculture and construction, two industries that have historically been considered the most hazardous (National Institute of Safety and Health, 2009).

Among the hazards in healthcare are percutaneous injuries (PI) caused by devices such as needles, scalpels, and suture needles capable of cutting or penetrating the skin (National Institute for Occupational Safety and Health, 2004). In the 1980s and 1990s, needlestick injuries in hospital-based healthcare workers were estimated at 600,000 to 800,000 injuries per year (NIOSH, 1999). By 2001, reported estimates of hospital-based needlestick injuries were approximately 600,000 annually in U.S. healthcare workers – at the lower end of the estimated numbers from the previous decade (Occupational Safety and Health Administration, 2001). Estimates released in 2004 indicate a possible decline in the number of sharps-related injuries in hospital-based healthcare workers to approximately 385,000 (but they are still estimated to injure over a 1000 workers each day) (Panlilio, Orelien, Srivastava, & al, 2004). As reported in all NIOSH and CDC (Centers for Disease Control and Prevention) references, the true magnitude of the problem is difficult to assess because information has not been gathered on the frequency of injuries among healthcare personnel working in other settings (e.g., long-term care, home healthcare, private medical offices). All estimates of needlestick injury must be adjusted for the problem of underreporting, which has been estimated to be as high as 50% of occupational percutaneous injuries (National Institute for Occupational Safety and Health, 2004). Although the apparent decline in hospital based injuries is an indication of progress, both reported and unreported injuries place healthcare workers at risk for almost 20 illnesses from bloodborne pathogens including Hepatitis B (HBV), Hepatitis C (HCV), and the Human Immunodefiency Virus (HIV) (CDC, 1998).

This paper is written a decade after passage of the U.S. Needlestick Safety and Prevention Act that required healthcare facilities to adopt measures to prevent exposures to blood and other potentially infectious bodily fluids, including steps to avoid needlesticks and to maintain current exposure control plans ("Needlestick Safety and Prevention Act of 2000," 2000). In spite of the new regulations and enforcement guidelines, needlestick injuries continue to be reported nationally and internationally. An electronic newsletter from the Hospital Safety Center reported that the latest Occupational Safety and Health Administration (OSHA) statistics show the agency's bloodborne pathogens standard was the most cited in general acute care hospitals in fiscal year 2009, as it had been in the previous nine years (Wallask, 2010). The ECRI Institute, an independent nonprofit company that evaluates medical devices and processes, published its list of the ten most dangerous technological hazards in healthcare in December, 2009 (Clark, 2009). These ten are described in the report as "problems that we believe are the most crucial right now, and that hospitals should consider putting at the top of their to-do lists… " (Clark, 2009). Ranked number six were accidental needlestick and sharps-related injuries. To prevent these injuries, the report recommended that facilities assure that healthcare workers are "trained and caution against making assumptions that a sharp is shielded just because the safety mechanism appears activated" (Clark, 2009).

Despite these recent warnings that workers continue to be at risk, the H1N1 influenza vaccination program in the fall of 2009 and winter 2010 provided a visible reminder that safer devices and needle use practices may be compromised or ignored when public protection campaigns command the attention of health officials. Images of workers, some nurses and other recently recruited non-professional "public health outreach workers" were prominent in the print and televised media. Those images frequently showed workers in crowded settings such as gymnasiums as they performed hundreds of injections often without gloves or adequate safety equipment.

While the facts of needlestick injury are well established in the literature, it was a personal journey as a nurse in San Francisco in the 1980s that introduced me to the issues of bloodborne pathogens, occupational risk, prevention, and ultimately, the study of occupational health. As a staff nurse at Saint Francis Memorial Hospital in San

Francisco, there was no way to know that we were one of the first hospitals to care for a patient infected with Kaposi's Sarcoma (the first recorded report of Kaposi's Sarcoma received by the CDC) and Cryptococcus as a result of what eventually was identified as Acquired Immune Deficiency Syndrome (AIDS) (Schilts, 1987). This scientific landmark was lost on the physicians and medical staff overwhelmed by the severe illness of the patients, fear of the unknown, and stress as friends and colleagues succumbed from these illnesses (Meyer, 1991). For the health professionals working in the cities of San Francisco, Los Angeles, and New York, what was occurring each day was not just a CDC Morbidity and Mortality Weekly Report (MMWR), but a life-threatening illness that put patients and some workers at risk. Living through these events as a night shift nurse propelled my professional advocacy for patients and staff to a national policy arena. As a nurse who was active in the professional nursing association union and the American Nurses Association (ANA), I provided testimony to a Congressional Committees in Washington DC and to the U.S. Office of Civil Rights about the risks and challenges of balancing safe non-discriminatory care to hospital patients while protecting healthcare workers from accidental injury.

Statement of the Problem

Historically and currently most needlestick injuries occur in nurses. They represent the predominant occupational group injured by needles and other sharps in part because they are the largest segment of the workforce at most hospitals. From the first published study on this subject in 1981 throughout the literature of 2010, studies show that nurses continue to handle needled devices and perform needle-related procedures that place them at risk for occupational exposure in all healthcare settings (Cullen et al., 2006; Doebbeling et al., 2003; R Gershon, 2008; R. Gershon et al., 2007; J. Jagger, Hunt, Brand-Elnaggar, & Pearson, 1988; McCormick & Maki, 1981; McCormick, Meisch, Ircink, & Maki, 1991; National Institute for Occupational Safety and Health, 2004; Trim & Elliott, 2003; A. M. Trinkoff, Le, Geiger-Brown, & Lipscomb, 2007). A preponderance of studies demonstrate an association between the hospital work environment, safety climate, and needlestick injury rates in hospital and nursing staff (L. Aiken, D. Sloane, & M. Klocinski, 1997; Centers for Disease Control Foundation, 2005; S. Clarke, 2007; S. Clarke, Rockett, Sloane, & Aiken, 2002; Doebbeling et al., 2003; R. Gershon et al., 2000; R. Gershon et al., 2007; A. M. Trinkoff et al., 2007).

Despite optimistic trends in reported injury rates, clinical areas in hospitals and particular devices and/or work practices remain problematic (Bakaeen et al., 2006; Makary et al., 2007). Although sharp devices can cause injuries anywhere within the healthcare environment, the CDC reports that the majority (39%) of injuries occur on hospital inpatient units, particularly medical floors and intensive care units, and in operating rooms (National Institute for Occupational Safety and Health, 2004). Injuries in the surgical setting continue to occur among all staff with nurses experiencing the second highest number.

Purpose of the Study

This study is designed to provide an exploratory analysis of hospital and market/population characteristics and their association with injury rates from sharps devices among all staff in California acute care hospitals in 2001, as well as injury rates among nurses working in those hospitals. The relative contributions of hospital characteristics (such as size, geographic location, type of ownership, and unionization) will be examined in relationship to each other as well as their relationship to sharps injury rates California acute care hospitals.

Significance of the Study

In 2000, there were an estimated 2,696,540 licensed Registered Nurses (RNs) in the U.S. workforce (Spratley, A., Fritz, & Spencer, 2000). At that time hospitals were the major employer of nurses, although the number of nurses employed in other sectors has increased since then. Occupational health and patient safety are now aligned in work emerging at the national level. The National Occupational Research Agenda (NORA) Healthcare and Social Assistance Sector 2009 report issued a powerful statement about the importance of providing a safe setting for all healthcare workers. As stated in the document, “Because patients and providers share the healthcare environment, efforts to protect patients and providers can be complimentary, even synergistic, when pursued through a comprehensive, integrated approach” (National Occupational Research Agenda Healthcare and Social Assistance Sector, 2009).

Numerous references can be found in the literature regarding research on the overall employee safety climate, nursing work environment, nurse satisfaction, patient safety and satisfaction, and quality of care. Gaps remain, however, with regard to the relationship of hospital financial status, geographic location, ownership, or presence of unionized nurses and healthcare workers on needlestick injury rates. This study may provide additional criteria to evaluate work environments that enhance the welfare of both patients and staff.

Chapter 2: Literature Review

Needlestick injuries in hospital-based healthcare workers were first reported in the 1980s and were estimated to account for at least 600,000 to 800,000 injuries per year (National Institute for Occupational Safety and Health, 2004). U.S. legislative and regulatory efforts to address needlestick injury began in 1999 with passage of the California Bloodborne Pathogens Standard, AB 1208 (National Institute for Occupational Safety and Health, 2009). In 2000, national legislation was enacted with the Needlestick Safety and Prevention Act ("Needlestick Safety and Prevention Act of 2000," 2000). By 2004, U.S. reports indicated that needlestick injuries in hospital-based healthcare workers had declined to approximately 385,000 per year (A. Panlilio et al., 2004). Needlestick injury patterns have changed from the first published study in 1981. How needlestick occur, how they are measured, and how such injuries may be mitigated have been examined in the literature. This chapter will discuss key research that has fundamentally contributed to the science of needlestick injuries and to the health and safety of hospital-based healthcare workers.

Search Methods

The body of literature related to needle safety and needlestick injury is extensive. A 2010 PubMed search with the term “sharps injuries” identified over 2700 titles. To narrow the scope of the search and provide a focused review for this study, the literature was limited to injuries from needles and syringes and to studies that include, but may not be limited to nurses in U.S. hospital settings. Additional articles describing needlestick injury measurement, modes of transmission, estimates of risk, non- hospital or non-nursing healthcare workers, work environment and psychological demands, health behaviors and beliefs, international trends, or other analyses of behaviors that contribute to risk or reporting were also examined for their foundational value to the study. The literature was searched using the electronic libraries of National Library of Medicine (NLM), PubMed, Cumulative Index of Nursing and Allied Health Literature (CINAHL) and the Cochrane library with articles limited to those published in English between 1980 and December 2010. Government websites including the CDC, NIOSH, and OSHA were also accessed.

In this chapter findings of the literature review will be organized to address three major subsets: 1) surveillance of needlestick injuries. 2) work environment factors that contribute to the likelihood of needlestick injury and 3) evaluation of key methods used to evaluate the effectiveness of devices intended to limit or prevent needlestick injuries.

Surveillance of Needlestick Injuries

Surveillance is a fundamental role of public health. It may be carried out to monitor changes in disease frequency or to monitor change in the prevalence of risk factors (Gordis, 2004). In occupational health, a surveillance program should identify cases of occupational illness or injury and/or monitor trends of occupational injury or illness (E. Baker & Matte, 1992). Epidemiology is concerned with assessing the association between an effect and the etiological agent and involves intensive data collection during a limited time (Levy, Wegman, & Halperin, 2000). Both surveillance and epidemiology have been employed to understand the occupational risk for needlestick injuries among healthcare workers. Described as occupational epidemiology, early sources of needlestick information included descriptive studies of employee health injury reports and epidemiological reports that estimated the occupational risk from needlesticks and the potential for infection from infectious agents (Levy et al., 2000).

The first report to document the number and cause of needlestick injuries in hospital personnel in the United States was published in 1981 (McCormick & Maki, 1981). The findings were the result of an occupational health injury investigation after a hospital received report of Hepatitis B transmission from a contaminated needlestick. The authors conducted a retrospective record review of reported workplace injuries to identify personnel and job activities at highest risk of needlestick injury; assess the morbidity, economic cost, and current medical management of these injuries; and to develop rational guidelines for prevention. During the four year review period at this hospital, needlestick injuries comprised almost 31% of reported injuries with nursing personnel accounting for 60% of all reported needlesticks. Most injuries occurred on the medical surgical patient care units with 90% occurring from five activities: disposing of used needles (23.7%), administering parenteral injections or infusion therapy (21.2%), drawing blood specimens (16.5%), cleaning up after patient care procedures in which needles were employed (16.1%), or recapping used needles (12%) (McCormick & Maki, 1981).

McCormick and Maki (1981) were the first to document that nurses experienced high numbers of needlestick injuries compared to other healthcare workers. The study also found high rates of needlestick injuries occurring in personnel not expected to be at risk such as housekeepers (McCormick & Maki, 1981). As a result, findings of this study helped establish a baseline for future needlestick injury reporting in hospitals.

As the era of AIDS began to unfold other researchers contributed to the awareness of occupational injury from needlesticks. Dr. Janine Jagger, an epidemiologist, was one of the first scientists to focus surveillance attention on devices used to perform routine healthcare procedures and how these may be related to injury events (J. Jagger et al., 1988). Jagger and colleagues calculated injury rates for categories of hospital personnel, unit characteristics, and devices involved in the injury based on employee reports of needlestick injuries. The authors estimated the rate of needlestick injuries for different devices using an original calculation that divided the number of needlesticks attributed to a device by the total quantity of the device purchased by the hospital during the study period.

Consistent with previous reports, this study confirmed that nurses and nursing students were most frequently injured (64%) followed by laboratory and other ancillary personnel (20%) and housekeeping (8%), while physicians and medical students accounted for only 3% of needlestick injuries (J. Jagger et al., 1988). This study found that injury rates were higher for devices that required disassembly. The authors also found that the practice of recapping had a direct impact on injury. These key findings were in distinct contrast to previous work that concluded needlestick injuries were caused primarily by carelessness or non-compliant healthcare workers and instead focused attention on the devices, work practices, and disposal systems (J. Jagger et al., 1988).

Although their report was limited to injuries related to hollow-bore needles, the findings became universally accepted as the authoritative analysis of device-related contributions to injuries and led to a link between equipment use and adverse effects. As a result Jagger and colleagues began to call for the development of safer devices in addition to standard prevention strategies that focused on workers' knowledge of risk and behavior change. Jagger's early projects eventually led to the establishment of a university based research center for worker safety, the International Healthcare Worker Safety Center as well as the creation of EPINet (J. Jagger & Perry, 2002, 2003, 2004). Developed in 1991, EPINet is a program used to systematically record information about percutaneous injuries and blood and body fluid exposures. The EPINet database is currently used to supplement injury data found in the CDC injury data base (J. Jagger & Perry, 2004; A. Panlilio et al., 2004).

While many researchers have replicated the methods of these two original studies (L. Aiken et al., 1997; S. Clarke, Schubert, & Ko¨rner, 2007; S. Clarke, Sloane, & Aiken, 2002; Dement, Epling, Østbye, Pompeii, & Hunt, 2004; Gerberding, 1989; R. Gershon et al., 2000; R. Gershon et al., 2009; Gillen et al., 2003; Jackson, Dechario, & Gardner, 1986; J. Jagger et al., 1988), others have expanded the science to evaluate the risks to non-hospital sectors, such as home health workers and to health settings around the globe (R. Gershon et al., 2009; Lipscomb et al., 2009; Scharf, McPhaul, Trinkoff, & Lipscomb, 2009). Still, unanswered questions remain concerning the occupational risks from needlestick injury including risk patterns and the likelihood of infection from an occupational exposure to bloodborne pathogens.

The CDC estimates that thousands of healthcare workers are exposed annually to Hepatitis B (HBV) (Centers for Disease Control and Prevention, 1997; Department of Labor, 1987). During the early days of the AIDS epidemic it was not known if HIV infection followed the same patterns as HBV exposure. Numerous studies were designed to better understand the etiology and treatment of HIV infection and to calculate the risk to exposed population segments, including healthcare workers. One of the first published studies regarding the occupational transmission of HIV, Cytomegalovirus (CMV), and HBV utilized the fundamentals of occupational epidemiology (Gerberding et al., 1987). In this study, 326 healthcare workers from two major medical centers in San Francisco were enrolled from December 1984 to March 1986. Medical personnel included attending physicians, medical house-staff, nurses, technicians, laboratory personnel, paramedics, dentists, and others who provided direct care to over 3000 patients infected with HIV. This study provided the first published calculation of the risk of acquiring HIV after a needlestick exposure, which was estimated to be <1% , certainly less than the risk of acquiring HBV after similar exposures (Gerberding et al., 1987).

More knowledge was gained than just the method of risk calculation, however, as the authors revealed their findings related to healthcare workers' perception of risk and risk aversion when working with patients known to be infected with a transmissible illness. The authors assumed that healthcare workers caring for patients with HIV would be particularly attuned to protection from occupational exposure. However, study results showed that workers admitted to poor compliance with recommended infection control procedures. The authors noted that this non-compliance would continue to place the workers at risk from HIV and other bloodborne infections (Gerberding et al., 1987).

As work regarding needlestick injury and HIV exposure evolved, other researchers have refined and perfected the fundamentals of occupational epidemiology. A report from Duke University Health System produced a sophisticated model to assess job risk and to guide occupational health injury prevention programs to target at-risk personnel (Dement, Epling et al., 2004; Dement, Pompeii et al., 2004). Key findings affirmed the patterns previously established by McCormick and Maki (1981) and Jagger (1988) with the predominant type of exposure occurring from percutaneous injury (72.1%), followed by mucous membrane exposure (17.7%) (Dement, Epling et al., 2004).

The Duke study assessed the distribution of injuries among workforce categories and reported that surgical technicians had injury rates nearly 8 times greater [Rate Ratio 101.8 (70.4-147.4)] than all other staff combined. Consistent with previous work, in-patient nurses continued to experience a high rate ratio for injury [>20.0 (Rate Ratio 23, 18-30)] (Dement, Epling et al., 2004). As has been confirmed in recent literature, the surgical arena is now considered one of the most likely settings for needle and sharp injuries as particular devices and/or work practices remain problematic (Bakaeen et al., 2006; Makary et al., 2007). An accompanying report by the same team at Duke Health Systems developed recommendations on the development of a reliable reporting system for occupational injuries (Dement, Epling et al., 2004; Dement, Pompeii et al., 2004). Key among their recommendations was a renewed call for the provision of safety products and a focus on work practices to protect high risk occupations, such as surgical personnel (Dement, Epling et al., 2004).

Results of surveillance and epidemiological research present a strong case for improved protections for workers. Compliance with recommended procedures or safer working practices has been shown not to be sufficient to prevent occupational exposure to bloodborne pathogens. To prevent injuries and protect workers, more needed to be known about the work environment in which nurses and other healthcare personnel were practicing.

Environmental Contributions to Needlestick Injury

There is a large body of research related to the concept of safety climate and the work environment. Often the terms "safety culture" and "safety climate" are used interchangeably, however, safety climate has come to be known as the overt manifestation of culture within an organization (Guldenmund, 2000). Safety climate is considered to be somewhat objective and can be measured in a semi-quantitative manner using self-administered questionnaires (Guldenmund, 2000). For purposes of this review, safety climate will be used to describe environmental factors that affect the health and safety of the workforce.

Most assessments of worker perspectives on safety climate are industry specific (Gillen, Baltz, Gassel, Kirsch, & Vaccaro, 2002). In healthcare facilities there are safety climate researchers who have applied their expertise to the study of patient safety, worker safety, or both (Coyle, Sleeman, & Adams, 1995; Feyer & Williamson, 1998; Flin, Burns, Mearns, Yule, & Robertson, 2006; Guldenmund, 2000; Mark et al., 2007; Singer et al., 2009; Singer, Lin, Falwell, Gaba, & Baker, 2008). The Agency for Health Research and Quality (AHRQ) produces a safety survey for nursing homes, hospitals, and physician offices with a primary focus on the impact of the climate on patient safety. In the Sharps Injury Prevention Workbook the CDC also provides a sample survey to measure healthcare workers' perceptions of safety specific to sharps injury (Centers for Disease Control and Prevention, 2008).

In a 2000 study on safety climate and the relationship to workplace injuries, researchers developed a tool to measure hospital safety climate with respect to institutional commitment to bloodborne pathogen risk management programs. The study also assessed the relationship between hospital safety climate and employee compliance with safe work practices (R. Gershon et al., 2000). A total of 1240 questionnaires were mailed to employees of a single large (1000+bed) urban medical center. Healthcare workers were stratified both by clinical unit and job title to determine which workers were at highest risk for blood and body fluid exposure (n=789), including 481 nurses (74.9%). The survey measured three major constructs of safety climate: demographics, self-reported compliance rates, and exposure history. Each item in the questionnaire was answered using a 5-point Likert scale (strongly agree to strongly disagree) (R. Gershon et al., 2000).

Results of the study showed that needlestick safety was related to compliance with safety practices. The highest levels of compliance included proper disposal of biomedical waste, proper disposal of sharps, and glove use. The lowest rates of compliance were reported for recapping contaminated needles, with 32% of employees reporting they sometimes or frequently recapped needles (R. Gershon et al., 2000). Compliance with infection control guidelines was found to be most strongly associated with cleanliness at the worksite [OR 3.30 (2.20-4.90) 95% CI]. After controlling for potential confounders, compliance was also found to be positively associated with greater senior managerial support [OR 2.30 (1.60-3.40) 95% CI]. Findings from this study provided valuable clues to areas of perceived support and barriers to care that may not be stringently associated with equipment, but relate to the larger subject of safe needle handling and injury prevention. The researchers suggested this safety climate tool could be incorporated into overall risk management programs and highlighted the opportunity for coordination among departments such as infection control and safety personnel (R. Gershon et al., 2000).

In other research the work environment has been found to have an influence on needle-stick related risks, injury rates, reporting patterns, and application of precautions to improve employee health (L. H. Aiken, D. M. Sloane, & M. Klocinski, 1997; S. P. Clarke, 2007; R Gershon et al., 2000; PW Stone, Clarke, Cimiotti, & Correa-de-Araujo, 2004; A. M. Trinkoff et al., 2007). Representative of this large body of research was a foundational study on nurses, the work environment, and associations with needlestick injuries (L. Aiken et al., 1997). In this multi-center study, the authors compared three sources of injury reports to evaluate how the organization of inpatient hospital care related to nurse and patient outcomes. The study evaluated unit and hospital types to determine if distinct AIDS care units and magnet hospitals were preferable to care received in general care units or non-magnet hospitals. Two outstanding characteristics of magnet hospitals are the principles of partnerships among and between staff and professionals and a vibrant practice environment (Buchan, 1999; McClure & Hinshaw, 2002; McClure, Poulin, Sovie, & Wandelt, 1983).

In this study, researchers examined whether self-reported injury rates among nurses differed from those of institutional records and what hospital characteristics might affect injury rates and risk for injury. This study was comprised of 732 nurses representing 40 different inpatient units from 20 hospitals in 11 cities, (L. Aiken et al., 1997). Hospital characteristics were described as organizational factors and were introduced in the analysis to determine if certain nurse, hospital, or unit characteristics were related to the likelihood of an injury occurring either during the data collection period or during the career of the staff nurse. Logistic regression models were used to develop odds ratios that indicated the effect size of certain descriptive characteristics. Findings revealed that nurses working on dedicated AIDS units were not found to have an increased likelihood of injuries. However, reports of needlestick/sharp injury were higher than the monthly institutional recorded rates of injury with nurses sustaining an average of 0.7-0.8 injuries per year, or between 3-4 injuries every 5 years (L. Aiken et al., 1997). The findings demonstrated that nurses who sometimes or often handled blood or body fluids were 50% more likely to be injured than those who rarely or never handled blood. Nurses who reported recapping needles were more likely to report an injury in both reporting phases (OR 1.773, 1.313-2.395. CO 95%). Organizational factors, such as the use of temporary staff, led to reports of higher injury rates while environments with increased autonomy (considered an attribute of magnet facilities) reported decreased rates.

This study was one of the earliest in the nursing literature to introduce the work environment as a factor in needlestick injury against a backdrop of practice patterns and device usage. This study also provided additional insights into concerns about the accuracy of institutional injury reports. Nurse self reports confirmed that recapping increased the risk of injury, prompting the authors to recommend specific strategies to reduce that risk (L. Aiken et al., 1997). These recommendations were consistent with research conducted during the prior 12-15 year time period (Center for Disease Control, 1985; J. Jagger et al., 1988; McCormick & Maki, 1981).

Subsequent studies evaluated safety climate, or an assessment of how employees perceive the safety of their work environment (Zohar, 1980). In these types of assessments, contributing factors for injury from needlesticks can be evaluated at the workplace level in the context of organizational commitment to safety. Sean Clarke assessed the association between work environment and occupational safety (S. Clarke, 2007). In this study a random sample (n=13,152) of registered nurses working in acute care hospitals in Pennsylvania were evaluated. Nurses were included in the final sample if there were at least 10 respondents from a hospital, which led to a sample of 11,512 nurses working in 188 hospitals. In addition to place of employment, participating nurses provided their personal demographics and career characteristics including clinical focus, years of experience and hours worked per week. Hospitals were grouped by size, teaching status, and major specialties (S. Clarke, 2007). This study utilized a measurement of the nursing work environment known as the Nursing Work Index (NWI) (Lake, 2002; Lake & Friese, 2006). The NWI is considered a highly valid and reliable assessment of nursing work environments and has been adopted by national measurement standard setting bodies such as the National Quality Forum (National Quality Forum, 2004). The NWI uses five practice environment scales to assess 49 work environment characteristics including nurse participation in hospital affairs, nursing foundations for quality of care, nurse manager ability, leadership and support of nurses, staffing and resource adequacy, and collegial nurse-physician relations. Additional hospital measures included staffing assignments and use of safety engineered equipment. The dependent variable was sharps injuries from devices used on patients in the previous year. In addition, hospital organizational variables (climate, staffing levels, and years of experience) were evaluated for each individual nurse as predictors of injury. Models were fitted to examine the relationship between nurse characteristics and the risk of a needlestick injury as well as the relationship of hospital characteristics to injuries.

No significant findings were apparent in the overall model among hospitals. However, when hospitals ranked in the top 25% on the NWI were selected, nurses were found to be approximately 20% less likely to sustain needlestick injuries both before and after nurse characteristics, hospital structural, and the use of protective equipment were controlled for (S. Clarke, 2007). In a fully adjusted model at the level of nurse characteristics, perioperative nurses were found to be twice as likely as medical-surgical nurses to be injured with more working hours being associated with greater needlestick risk. Overall, 9.6% of all the nurses reported a sharps injury in the preceding year, as compared with 7.2% of nurses who reported injuries and worked in hospitals with the most favorable work environments (S. Clarke, 2007). Use of self-recapping needles and safety-lock syringes were associated with decreased risk in the unadjusted models, but not after nurse characteristics and the use of needleless intravenous tubing were controlled for (S. Clarke, 2007). Surprisingly, results of the study found that neither staffing levels nor mean years of experience were predictors in the fully adjusted model. No evidence was found that there was greater use of safety-engineered equipment by nurses in hospitals with more favorable practice environments, although the author did suspect that the operational definitions about devices may have been problematic as used in the survey (S. Clarke, 2007).

Other researchers investigating nursing work environments have further elaborated on the linkage between working conditions, needle use, and needlestick injuries. In a study by Trinkoff et al. (2007) nurses from two U.S. states were randomly selected to participate in a mail survey regarding nurse demographic characteristics and work environment characteristics such as hours of work and use of overtime as they relate to needlestick injury. The number of needles used per day was estimated by identifying the midpoint of the response range (except for reports of 10 or more) of needles used (A. M. Trinkoff et al., 2007). Similar to the study by Clarke (2007), nurses in this study were asked about their needlestick injuries and whether the needle that was involved had a safer design (A. M. Trinkoff et al., 2007). Work-schedule variables were derived from the Standard Shiftwork Index and the terms and definitions were verified with content experts from NIOSH. Nurses were asked to recall their work schedule for all jobs held for the past six months and report actual hours worked, including overtime. The impact of psychological and physical demands were measured using the Job Content Questionnaire (Karasek, 1985).

Findings indicated that 16% of nurses reported a needlestick injury in the past year. One-third of the injuries were from needles with safer designs. The age-adjusted odds of needlestick injury for nurses with medium or high frequency of needle use (21-40 times per day) was 2-3 times more likely than for nurses who performed 0-20 needle-use tasks per day [OR for medium 2.55 (1.98-3.29), 95% CI], [OR for high 3.64 (2.41-5.50), CI 95%]. When injured, 81% of nurses stated they reported the injury if it involved a possibly contaminated needle. While this reporting rate is higher than other reports in the literature (Gerberding et al., 1987; McCray, 1986), the rate was not further assessed (A.

M. Trinkoff et al., 2007). Contrary to the study by Clark (2007), Trinkoff and colleagues concluded that long work hours, as well as other adverse scheduling practices, contributed to a significant increase in the risk of needlestick injury. Implementing controls for physical job demands and physical exertion, as well as controls in work schedules, could further prevent needlestick injury.

Effectiveness of Devices to Limit or Prevent Needlestick Injuries

When discussing needles and needlestick injuries the term device can be used to describe a wide range of safety engineered needles, syringes, and related equipment. As the first generation of new and innovative devices were introduced into the healthcare system, descriptive studies were published chronicling the advent of these devices and how nurses and other personnel were responding to them (D. Rivers et al., 2003; Skolnick, LaRocca, Barba, & Paicius, 1993; Younger, Hunt, Robinson, & McLemore, 1992). An example of one such study was conducted by Haiduven and colleagues and is included as representative of this era. Between 1986 and 1990 the employee health and infection control office at a large California hospital joined forces to reduce needlestick-related injuries (Haiduven, DeMaio T., & Stevens, 1992). Responding to reports and advisories to reduce healthcare worker exposure to bloodborne pathogens, the program encompassed the areas of communication, education, and more convenient placement of needle disposal containers. At the time this study was conducted there were few equipment or device options available except for traditional needles and syringes. Sharps containers that we are familiar with today were not yet in wide use.

The communication component of the study included an injury review board composed of nurses, senior hospital officials, quality assurance officers, safety personnel, and product evaluation committees. Education was provided during the 5-year study period with targeted education sessions conducted for healthcare personnel in high risk areas, such as the surgical suite and laboratory, as well as all new nursing personnel and physicians. Additional needle safety handling programs and presentations were also conducted each year. Finally, needle disposal containers were installed in patient care areas and near points of care.

Data was collected from all employees who reported contaminated needlestick injuries on injury report forms. Needlestick injuries reported by nursing personnel accounted for 73-76% of all injuries (Haiduven et al., 1992). Needlestick injury rates were descriptively reported and linear regression was used to test the null hypothesis that more convenient placement of needle disposal boxes, education, and communication would not decrease the overall rate of needlestick injuries or those injuries occurring from recapping. Results of the study showed a 60% decrease in injuries reported during the study period ($p=.003$) and an 81% decrease in injuries related to needle recapping ($p=.005$).

One limitation of this study was that strategies to reduce occupational injury were being implemented at the same time other needle safety devices were under evaluation making a final assessment of effectiveness difficult. The use of such devices could have confounded findings about recapping practices not related to the study's three identified interventions. Nonetheless, the study contributed a model of evaluation of multiple, simultaneous strategies to reduce occupational injury.

Another device evaluation study was conducted at a large metropolitan hospital during a period of rapid safer device manufacturing and implementation across the country (Sohn, Eagan, Sepkowitz, & Zuccotti, 2004). The study was designed to assess the effect of safety engineered devices on percutaneous injuries with special emphasis on injuries associated with a higher risk of blood-borne pathogen exposure. The study calculated injuries by employee group, activity, and device type (Sohn et al., 2004). All employees who reported percutaneous injuries during the study period were included in the sample. There were 529 blood exposure events reported with 449 of those classified as percutaneous injury. The investigators ranked each injury as either high or low risk based on the likelihood of bloodborne pathogen transmission at the time of injury.

In February 2001 the hospital introduced a facility-wide safer-needle system to replace conventional equipment used for IV therapy, blood collection, IV insertion, and injections (Sohn et al., 2004). All devices were evaluated and pilot tested at the institution with explicit selection criteria. All patient care personnel were required to attend a training session during the months prior to implementation. The investigators established a monthly average rate of injuries for the pre and post intervention periods and then derived a mean annual incidence rate per 1000 full time equivalents (FTEs). After implementation of the safety-engineered devices a monthly average of 4.92 (SD, ± 2.97) percutaneous injuries were reported. This represented a decrease in the mean annual percutaneous injury incidence rate from 34.08 (SD, ± 9.49) per 1,000 FTEs to 14.25 (SD, ± 8.61, $P < .001$) per 1,000 FTEs (Sohn et al., 2004). As found in previous research, nurses represented the greatest proportion of employees reporting needlestick injuries during the pre-intervention period (54.1%), followed by ancillary staff (14.4%), technicians (9.5%), and medical staff (9.2%). However, employees in all categories experienced significant decreases in percutaneous injury rates (74.5%, $P < .001$; and 61.5%, $P = .03$, respectively) after implementation of safety devices (Sohn et al., 2004). Overall, the researchers reported lowering the overall incidence of percutaneous injuries by more than 50%, which they attributed to the presence of the new safety devices (Sohn et al., 2004).

This study was one of the first conducted and reported after passage of the Needlestick Safety and Prevention Act of 2000 ("Needlestick Safety and Prevention Act of 2000," 2000) to address whether implementation of safety-engineered devices would decrease injuries from needled devices. The study design and findings were enhanced in large part because the facility had been using a standardized reporting system which allowed for sufficient data comparison. A key finding of this study was the continuation of injuries caused by the new safety engineered devices. One explanation was that these injuries could have occurred when staff used devices without adequate training in safe usage. This issue was left unresolved in the Sohn et al. (2004) publication but remains a concern whenever newer devices are introduced into the work environment (Alvarado-Ramy et al., 2003; Cullen et al., 2006).

Healthcare workers who perform phlebotomy procedures are known to be at risk for needlestick injury. Alvarado-Ramy and colleagues focused on this injury-prone procedure in their multi-site study (Alvarado-Ramy et al., 2003). In this study 10 university-affiliated hospitals were recruited to participate in a two-phase study. In phase one baseline rates of percutaneous injury from conventional phlebotomy devices were collected over a 10 month period from all 10 sites. In phase two, safety engineered phlebotomy devices were assessed over a 12 month period in the six hospitals that completed both phases (Alvarado-Ramy et al., 2003).

Evaluation committees from participating hospitals selected three safety engineered devices for use in this study. Each of the devices required worker activation of the product safety feature. Before introducing the devices, each hospital conducted a comprehensive training program that included hands-on experience with the new equipment. To verify user reports about device use and activation of safety features, the researchers examined the contents of a sample of disposal containers at each hospital. In addition, each hospital used a uniform data collection form to document injuries including a subjective question to workers regarding the preventability of the exposure (Alvarado-Ramy et al., 2003). Each hospital had a unique pre-existing surveillance system. In an effort to control for that variability, the researchers designed an anonymous survey to assess the rate of underreporting of needlestick injuries in each system (Alvarado-Ramy et al., 2003).

Because estimated rates of injury by device and occupation were similar in hospitals using the same devices, data were aggregated to permit comparison of injury rates for safety engineered devices and conventional devices. Safety vacuum-tube design phlebotomy devices demonstrated a reduction in injuries after adjustment by occupation, with the blunted and recapping sheath providing a statistically significant injury reduction. Both the bluntable phlebotomy needle and the phlebotomy needle with recapping sheath achieved similar reductions in percutaneous injury rates (76% and 66%, respectively; $P = .003$). Although the resheathable winged steel needle also showed a 23% reduction in percutaneous injury rates, this reduction was not statistically significant

(*P* = .07). Examination of phlebotomy devices found in the audited sharps disposal boxes revealed 89% were safety engineered devices. Activation of the safety feature on the devices varied among hospitals with rates ranging from 17% to 67% (Alvarado-Ramy et al., 2003). Similar to the work of Sohn et al. (2004), safety device activation rates were related to training in the proper use of the safety equipment (Alvarado-Ramy et al., 2003).

Results showed that nurses sustained the largest proportion (42%) of percutaneous injuries followed by physicians, (26%) medical students, and phlebotomists (4% each). Eighty-three percent of the injuries occurred during the performance of routine procedures. Staff members were not overwhelmingly supportive of new device adoption in this study, with only 44% favoring one or more safety devices and 33% indicating they favored conventional devices. However, survey results showed that 94% of healthcare workers who were injured believed the injuries were preventable. In injuries resulting from non-safety devices 77% believed the injuries were preventable. Anonymous surveys to assess underreporting produced findings that were similar among occupations across both phases of the study. Subjects acknowledged they reported 302 (54%) of 563 percutaneous injuries sustained during the previous year. Phlebotomists had the highest reporting rate (91% of their injuries) with nurses (68%), medical students (35%), and medical residents (31%) reporting their injuries (Alvarado-Ramy et al., 2003). These rates remain within the range of the estimates of underreporting, such as the estimates created by Hamory (Hadaway, 2001; Hamory, 1983, 1984).

Economics of Needlestick Injuries and Safer Devices

In reviewing the literature regarding needlestick injury, abundant references were found regarding the economic costs of injury (Boden, Biddle, & Spieler, 2001; Chiarello, 1995; Fisman, Mittleman, Sorock, & Harris, 2002; J. Jagger, Bentley, & Juillet, 1998; Laufer & Chiarello, 1994; Lee et al., 2005; Leigh et al., 2007; Pruss-Ustun & Rapiti, 2005; Prüss-Üstün, Rapiti, & Hutin, 2003; Stock, Gafni, & Bloch, 1990; Yassi, McGill, & Khokhar, 1995). Current cost estimates for a sharp injury were reported in the CDC Workbook, which cited a 2007 report on the costs of managing occupational exposures to bloodborne pathogens (Centers for Disease Control and Prevention, 2008; O'Malley, 2007). Those costs included direct medical costs ranging from $71 to $5000 per exposure, as well as lost time, emotional cost, and the possibility of long-term costs (O'Malley, 2007).

Other approaches to estimating costs have also been published. Fisman et al. (2002) used a contingent valuation method to assess “willingness to pay” to avoid sharps-related injuries among recently injured healthcare workers. Contingent valuation is a survey-based technique that estimates the valuation of non-market resources. While these resources may not have a market price, they do have value since some aspect may have utility to the user (Mundy & McLean, 1998). In the Fishman et al. (2002) study, workers were presented with the option of paying out of pocket for a hypothetical injury-prevention device that might reduce their risk of an occupational exposure. The authors concluded that the high median amount workers were willing to pay to avoid injury from an infected source ($1270) suggested that intangible aspects of worker injury, such as anxiety and distress, may equal costs associated with the medical evaluation of these injuries (Fisman et al., 2002). As a result, the authors suggested that any economic analysis of injuries should include medical expenses as well as the psychological and sociological factors to derive a comprehensive and more accurate estimate (Fisman et al., 2002).

Some of the most detailed information about the possible costs and savings of safer medical devices was contained in a document issued by the Government Accounting Office (GAO). Issued in response to a request from a U.S. Congressional Committee, the report provided information about the potential benefits and costs of changes that would be mandated under the proposed Needlestick Safety and Prevention Act (P.L.106-430) ("Needlestick Safety and Prevention Act of 2000," 2000). In the GAO report were estimates provided by OSHA that showed the average cost of a needle with a safety feature ranged from $.07 to $.15 for a syringe/needle combination, from $.15 to $.30 for a blood collection needle or set, and about $.70 for an intravenous catheter. While the cost of devices with safety features was more than those without, the GAO estimated there could be a reduction of 69,000 needlestick injuries in one year with the use of needles with safety features. The report also included a cost-benefit calculation of safety devices compared to the cost of injuries. Deriving information from the published literature at the time, they reported estimated expenditures at that time were approximately $500 to $3,000 per injury sustained. They further estimated that by eliminating 69,000 needlesticks through the use of devices with safety features, there would be a reduction in post-exposure treatment costs between $37 million and $173 million per year in the United States.

The studies reviewed present a small cross-section of the literature that has informed the field of occupational health injury prevention related to needlestick injuries in hospital-based nurses. Findings have consistently shown that nurses sustain high levels of needlestick injuries. Despite the introduction of new safety devices and regulation and enforcement guidelines, needlestick injuries continue to be reported. The relationship between hospital characteristics, economic concerns, and healthcare worker characteristics continues to be a topic of investigation.

Conceptual Framework

"Money makes the world go round"

Whether viewed as a catchy song from the musical Cabaret or a sad reality, economics (money) often explains why some actions are taken and others are not. Economics can be applied to actions taken by healthcare institutions as well, particularly actions taken to protect workers from unnecessary needlestick injuries. Medical care is a process or activity in which certain inputs or factors of production (such as doctors' and nurses' services, services of medical instruments and equipment, and pharmaceuticals) are combined in varying quantities to yield the output called *medical care*. Hospitals are both suppliers of services and purchasers of goods and services. Health professionals, technology including pharmaceuticals, and healthcare facilities are considered producers of health services while individuals, insurers, and the state are the purchasers or demanders of healthcare services (Folland, Goodman, & Stano, 2004a).

Market Model and Injury Prevention

Factors that influence supply include technological change, prices for supplies and goods needed to provide health services, staffing costs, and the size of the industry. Factors that influence demand include prices of related goods, insurance, income, preferences, population, and disability (Folland, Goodman, & Stano, 2004c). Whether a hospital is choosing capital inputs, such as physical space and equipment, or labor inputs such as professional, technical, or clerical workers, the choices are intended to keep production costs as low as possible so they can sell their output in a competitive market. Hospitals, like any other business, must decide how to combine resources to produce a desired quantity and quality of patient care services (Buerhaus, 2009). Most acute care hospitals are paid according to fixed rates for a substantial portion of their patient population and thus face strong economic incentives to use the least costly combination of inputs (Buerhaus, 2009). Purchasers, on the other hand, whether they are patients, employers, or insurance plans, have an economic incentive to search for providers that can supply a given quality product at the lowest price (Feldstein, 1998).

Successful hospital management encompasses the common economic goal of efficiency, or getting the most from available resources (Scott II, Solomon, & McGowan, 2001). Innovation and new technologies place additional limits on cost as it relates to healthcare (Feldstein, 1993; Folland et al., 2004a). In fact, a number of occupational health proponents have been critical of the hospital industry for using the cost of new and safer devices as a rationale to delay implementation (Beekmann et al., 2001; Castella, Vallino, Argentero, & Zotti, 2003; Culver, 1997; Fisman et al., 2002; J. Jagger et al., 1998; J Jagger, Hunt, & Pearson, 1990).

Healthcare worker exposures from needlestick injury occur as the result of a combination of three factors: worker education, work practices, and the devices used to provide care. By the 1990s it was determined that prevention efforts targeting all three factors could reduce accidental needlesticks by as much as 90% (Centers for Disease Control and Prevention, 1998). Publications from as early as the 1980's recommended use of modified equipment to both protect workers and reduce injuries (J. Jagger, 1989; J. Jagger et al., 1988; McCormick & Maki, 1981). Despite this only a handful of hospitals joined the National Campaign for Health Care Worker Safety, a program to replace standard equipment with safety devices (Algie, Arnold, & Fowler, 1999). These facts illustrate the complex interaction between healthcare economics and safety. Health economists are divided over whether the free market model of economics is appropriate to apply to healthcare systems (Fuchs, 1996). From an economic perspective, it could be said that market forces are not sufficient to affect a cost-saving and life-saving strategy of needlestick prevention. Or conversely, perhaps it is the market at work that limits the demand for new products, keeps the prices of those products too high, and delays the widespread onset of affordable and widely available new products.

Ecological Model and Injury Control

While the market model is important in an analysis of injury prevention, it is not the only factor to consider. The review of injury prevention literature disclosed a common theoretical model, the ecological model (Clarke, 2004). One of the earliest injury prevention theories to encompass environmental factors was the Haddon Matrix (Haddon, 1980a, 1980b; Haddon, 1999). This injury prevention model was based on the classic epidemiologic triad of host, agent, and environment, adding a new axis—the time sequence. The environment is sometimes expanded to include both physical environment (i.e., surroundings that contribute to the occurrence of potentially injury-producing events or to injury) and social environment (i.e., the sociopolitical milieu affecting the process, which could include cultural norms or mores) (Runyan, 2003). Using environmental theory to influence public policy regarding injury control requires an additional perspective of value criteria in the decision making process (Figure 1) (Runyan, 1998). The value criteria includes perspectives and dimensions such as effectiveness, cost, equity, preferences of the affected community or individuals, and feasibility (Runyan, 1998). Adding the value criteria would provide additional information which can then determine which approach is best suited for a specific problem (Peek-Asa & Heiden, 2008).

Figure 1. Three Dimensional Haddon Matrix for Decision Making

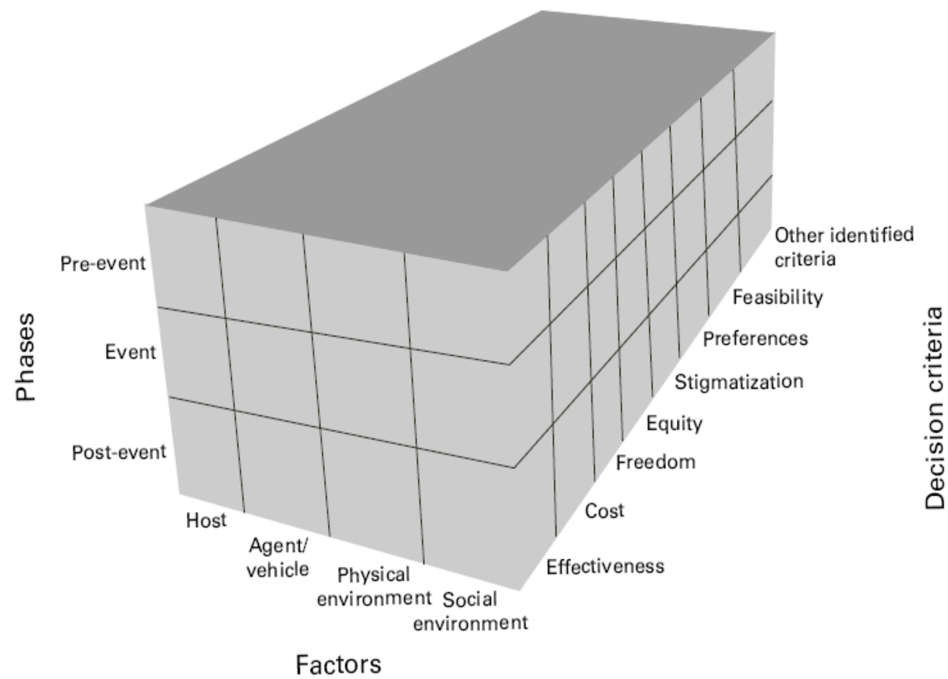


Figure 1 Proposed three dimensional Haddon matrix.

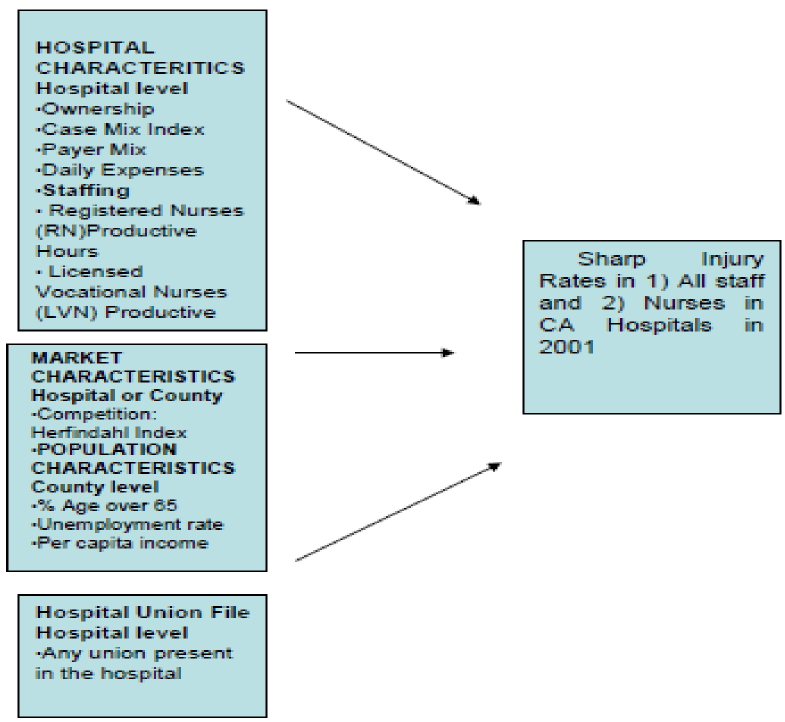
Source: From Runyan (Runyan, 1998, pp. 304)

One of the first safety areas to reference the work of Haddon was occupational health and safety (Elkington, 2002). Public and community health proponents and occupational health specialists have adopted models of injury control based on the framework of prioritization, passive protection, and prevention (S. Baker, 1975; S. Baker, Teret, & Daub, 1987; Haddon, 1973; Haddon, 1980a, 1980b; Haddon, 1999). It is important but distressing to note that contemporary needlestick injury prevention literature continues to recommend passive protection as the most reliable way to reduce occupational exposures (Tosini et al., 2010).

Occupational health and patient safety are now aligned in work emerging at the national level. That integration could be defined as an ecological model of patient and worker safety in the healthcare environment. Recent publications such as the National Occupational Research Agenda (NORA) Healthcare and Social Assistance Sector report emphasize the importance of providing a safe setting for all. As stated in the document, "Because patients and providers share the healthcare environment, efforts to protect patients and providers can be complimentary, even synergistic, when pursued through a comprehensive, integrated approach" (National Occupational Research Agenda Healthcare and Social Assistance Sector, 2009). An ecological model may convey "connectedness" among programs, priorities, and decisions made by hospitals as they choose how much and what type of capital and labor to purchase and the how to combine these resources (Buerhaus, 2009). As stated by another health services researcher, Barbara Mark…" there is an emerging consensus that successful safety initiatives will depend on a theoretically sound understanding of the interrelationships among individual, environmental, and organizational factors that affect safe job performance"(Mark et al., 2007).

In this study an ecological model is used as an organizing framework to incorporate the environmental and hospital interrelationships addressed in the examination of needlestick injuries in California hospitals in 2001. The underlying foundations of the model propose that understanding risk and protective factors for needlestick injury requires an understanding beyond the measure of individual protective behaviors but as well, the environment in which they occur. Hospital, market, and individual characteristics all combine to affect the rates of needlestick injuries. In this study market model and ecological models are combined as an organizing framework to incorporate the environmental and hospital interrelationships addressed in the examination of needlestick injuries in California hospitals in 2001. A working model for the proposed study is shown in Figure 2.

Figure 2. Foley Model of Likely Hospital, Market, and Population Characteristics



For quite some time, little was known about the true costs of injury and illness associated with needlestick injuries, and even less about the cost of products or purchasing practices regarding safer devices. Use of the ecological model to evaluate needlestick injuries allows economic principles to be connected with an injury prevention framework. However, while adequate, the ecological model does not sufficiently convey the relationship among all of the characteristics or factors that may affect needlestick injury rates. This research will test for the relative contribution of different independent variables to identify those likely to be predictive of needlestick injury rates of hospital based nurses in California acute care hospitals in 2001.

Chapter 3: Methods

Study Design

The purpose of this cross-sectional, secondary data analysis study was to examine the relationships between factors that may be associated with needlestick injury rates in hospital staff and nurses working in California acute care hospitals in 2001. Non-published injury data from the Bloodborne Pathogens Project, Sharps Injuries in California Health Care Facilities and Agencies 1997-2001 (Sharps Injury Study, Principal Investigator [PI]-Marion Gillen, PhD, RN) were used to create the numerator for the rates. Denominator data were calculated from pre-existing public files from the California Office of Statewide Health Planning and Development (OSHPD) that had been integrated with original data collected by the Sharps Injury Study. Other independent variables were created from publically available datasets including OSHPD, the Area Resource File (ARF), and other sources. Only data from general acute care hospitals were examined. This current analysis is limited to the 2001 data to allow for an evaluation of the model using a cross-sectional design. Once the model is further refined, this analysis will be repeated for the period 1997-2001 to evaluate changes in injury rates and the association with hospital characteristics. This study received approval from the University of California, San Francisco (UCSF) Committee on Human Subjects through June 2011.

Sample

Primary data for this investigation were derived from the Sharps Injury Study (see above), which collected needlestick and percutaneous injury reports from California healthcare facilities for the time period 1997-2001. These unpublished data were collected by researchers from the University of California, San Francisco, (UCSF) in conjunction with the Occupational Health Branch of the California Department of Health Services as part of a NIOSH-funded research project. All licensed hospitals in California were invited to take part in the study and to submit data for the requested time period. Inclusion criterion for this initial study was licensure by the state of California as a healthcare facility. Hospital identifiers and addresses were obtained from the Licensing and Certification list maintained by the California Department of Health Services. Approximately 468 hospitals were invited to participate by completing a one-page form in which they provided the total number of sharps injuries (needlestick and other percutaneous injuries) for each year in all staff, and the total number for registered nurses (RN) and licensed vocational nurses (LVN). The facilities were also asked to provide information on the number of Full Time Equivalent (FTE) hospital staff; however, these data were not used in the original study due to reporting irregularities. Further, not all hospitals provided complete information and some were not classified as acute care hospitals, excluding them from the study. In total, 417 general acute care facilities were included in the final sample for the 2001 analysis. In addition, publicly available data from California OSHPD financial files, the California ARF, and a California hospital union file were also obtained for use in the analysis. A copy of the Sharps Injury Study survey tool is attached as Appendix 1.

Variables and Measures

The original survey collected sharps injury data from the time period 1997-2001; however, for this study only data from 2001 were used. Data from the OSPHD financial database, obtained by original study staff, supplied information regarding hospital characteristics including staffing, available bed size, and financial data. Additional databases were used to obtain market characteristics, county-level data, and union participation by hospital. Table 1 lists all variables and data sources used in this secondary analysis.

Dependent variable. The Bloodborne Pathogens Project of the University of California, San Francisco, and the Occupational Health Branch of the California Department of Health Services collected hospital-level data using a one-page questionnaire. These data were provided for secondary analysis with permission from the principal investigator. Survey variables used in the current analysis included (1) the total number of needlesticks and other percutaneous injuries in 2001 reported among all hospital staff and (2) injuries in RN and LVN staff at participating California acute care hospitals.

Denominator data used to calculate injury rates were obtained by original study staff from files maintained by the California OSHPD within the California Health and Human Services Agency, which requires hospitals to report data within prescriptive time frames. OSHPD maintains several types of reports including the Hospital Annual Financial Disclosure Report, Utilization Data, and Hospital Discharge Data. (California Department of Public Health, 2010; Gillen et al., 2003; Office of Statewide Health

Planning and Development (OSHPD), 2008). To illustrate the data collected from each hospital, a page from the OSHPD form is provided as Appendix 2.

Hospitals report data to OSHPD in either a fiscal year (FY) or calendar year (CY) format; therefore, all data related to hospital characteristics were adjusted in the original study to account for different reporting periods. Hence, if a hospital reported data in a FY format, OSHPD data from 2000 and 2002 were used to create a year's worth of reporting corresponding to the 2001 year calendar format. Denominator variables were also corrected to reflect 365 days of reporting.

Information for the study denominator was obtained primarily from the Hospital Annual Financial Disclosure (AFDR) report (subsequently referred to as the financial report) and was used to calculate rates of injury. Multiple denominators, created in the original study, were evaluated for appropriateness based on the literature and knowledge of the field. However, the final denominator that was selected for calculation of rates was "available beds." This variable is a more conservative value than licensed beds and is generally considered a more accurate descriptor of operating capacity. While it is a measure of hospital size, it is corrected for the somewhat over-inflated variable, "licensed beds," or the underestimate that may occur when hospitals report "staffed beds" or "occupied beds."

The rate created using "available beds" incorporated all injuries reported by hospitals in the numerator (for all staff and for nurses) and was multiplied by 100 to create a more interpretable figure.

Model variables were selected *a priori* based on a thorough review of the literature regarding sharps injuries, healthcare worker injury risks and work practices, and the structure and operation of acute care hospitals.

Independent variables. Independent variables for this study consisted of demographic and financial hospital data, as well as days of care and discharges by payer source. Hospital specific data were obtained from OSHPD, market characteristics from the Area Resource File, and union information from a secondary source.

Hospital Characteristics. Variables used in this study included ownership (e.g., non-profit, government and district, and for-profit), payer mix actualized as discharges by payer source (e.g. Medicare), case mix index, length of stay (excluding long term care), daily hospital expenses, and productive nursing hours. California hospitals are categorized in the OSHPD data according to types of ownership: stand alone non-profit, non-profit corporation, stand alone for-profit, for-profit corporation, government, and district. For purposes of this analysis, these six types were collapsed into three categories: non-profit, for-profit, and government and district. Payer Mix is a term used to describe hospital patients categorized by which source will pay for their care. Each type of payer is presented as a percentage of the total patients discharged, and the payer sources combined total 100%. The case mix index (CMI) is a cumulative weight calculated by OSHPD to adjust the average cost per patient per day for a given hospital. Each hospital calculates the CMI as the sum of the Medicare Severity-Diagnostic Related Groups (MS-DRG) weights divided by the total number of discharges. Length of stay is defined as annual reported total days of care divided by the number of discharges for acute care. Daily hospital expenses are defined as annual reported expenses divided by the number of patient discharges. Finally, productive nursing hours were reported for RN and LVN staff as the number of paid hours worked, not including vacation or sick leave, rather than the number of full-time equivalent personnel. This total represents a more accurate description of hours spent in direct care activities.

Hospital Market and Population Characteristics. Four variables were used to measure hospital market and population characteristics: competition in the healthcare sector, percent population over age 65, per capita income, and unemployment rate per county. Competition in the healthcare sector was measured by the Herfindahl-Hirschman Index (HI). Each hospital has a unique HI score, which represents the number of available beds reported by the hospital divided by the number of available beds in the Health Services Area (HSA) in which the hospital is located. Percent of population over the age of 65, per capita income, and unemployment rates were obtained from ARF files using data from the 2000 census and Bureau of Labor Statistics (Health Resources Service Agency (HRSA), 2000-2005). The population percentage was calculated from the number of residents over age 65 divided by the total population per county. Per capita income was calculated by dividing the total personal income of all residents in the county by the resident population. Finally, unemployment rates were calculated by dividing the number of unemployed county residents by the civilian labor force in the county.

Union Participation by Hospital. This variable indicates whether or not hospital staff was represented by a nursing union or any other type of union. These data were obtained from two UCSF researchers, Dr. Joanne Spetz and Dr. Jean Ann Seago. They started collecting this information in 1995 through a phone survey of California hospitals to ascertain whether hospital employees were represented by collective bargaining, and if so, by which unions. Spetz and Seago continually update the data, and this study also updated the data to correct for missing items. The file is maintained using OSHPD unique identifiers. While these data are an unpublished, the investigators have published studies using this information (Seago & Ash, 2002). This variable was initially proposed to evaluate differences in injury rates between hospitals with or without nurse unions. However, as no differences were noted among hospitals by union type, the variable was coded as presence of any union.

After examining the union status in hospitals, it was determined that hospitals with a nursing union had other unions as well. Hence, because no differences were noted among hospitals by union type, this variable was changed to represent the presence or absence of any union.

Table 1

Study variables used in the analysis for sharps injury rates in acute care hospitals of California in 2001

Variable Name	Operational Definition	Data Source	Variable Type
Hospital Characteristics			
*Number of Available Hospital Beds	Categorized as the number of available beds which physically exist and are available for overnight use regardless of staffing.	OSHPD	Continuous
Ownership	Denotes ownership and /or legal organization of a licensee and has a range of categories Decision: Three categories were created from six types: Non Profit, Profit and Government/District.	OSHPD	Categorical

Variable Name	Operational Definition	Data Source	Variable Type
Payer Mix	Patient days and/or discharges are spread among a total of 10 categories: Collapsed into (1) Medicare; (2) Medi-Cal; (3) Indigent; (4) Third Party; (5) Other Payors; and (6) Total Decision: In order to determine the percent of discharges by payer source, four categories were created (Medicare, Medi-Cal, Third Party, and Other) and the number of discharges was divided by the total number of calculated discharges.	OSHPD	Continuous
Major Source of Payment	Each hospital was evaluated for its major payer source Decision: Four categories were created: Medicare, Medi-Cal, Third Party, and Other.	OSHPD	Categorical
Case Mix Index (CMI)	A cumulative weight, calculated by OSHPD, used to determine reimbursement and a measure of patient severity.	OSHPD	Continuous
Length of Stay (LOS)	Calculated by OSHPD by dividing Total Hospital Days by Number of Discharges, excluding Long Term Care.	OSHPD	Continuous
Daily Expenses	Derived by OSHPD by dividing inpatient operating expenses by patient days and/or patient discharges.	OSHPD	Continuous
RN Productive Hours	Reported in the OSHPD file as number of productive hours (paid hours, not including vacation or sick leave, etc.) worked by RN staff, rather than the number of full-time equivalent personnel.	OSHPD	Continuous
LVN Productive Hours	Reported in the OSHPD files as the number of productive hours (paid hours, not including vacation, sick leave, etc.) worked by LVN staff, rather than the number of full-time equivalent personnel.	OSHPD	Continuous

Variable Name	Operational Definition	Data Source	Variable Type
Market and Population Characteristics			
Herfindahl Index (HI)	Used to determine the degree of competition in a regional market. The HHI is calculated as the sum of squared market shares in a Health Service Area (HSA). HSAs are clusters of counties defined by locations where county residents obtain hospital care. In California, there are 14 HSAs.	OSHPD And Dr. Serratt	Continuous
Percent of Population over age 65 per County	Reported in the Area Resource File (ARF), a database national county-level health data for each county in the United States. The ARF file for 2005 included population statistics for 2001.	ARF	Continuous
Unemployment Rate per County	Reported in the ARF database national county-level health data for each county in the United States. The ARF file for 2005 included population and labor statistics from BLS for 2001.	ARF	Continuous
Per Capita Income per County	Reported in the ARF database national county-level health data for each county in the United States. The ARF file for 2005 included population and income statistics for 2001.	ARF	Continuous
Union Participation			
Presence of Any Union	The presence of a union (organized workforce for purposes of collective bargaining) in California acute care hospitals in 2001 and matched with data from the Sharp Injury Survey by unique OSHPD identifier.	Unpublished File from Drs. Spetz and Seago	Dichotomous
Sharps Injury			
*Needlestick and Sharps Injuries in All Staff in CA	The California Sharps Injury Study collected the total number of needlestick and sharps injuries in all staff in 2001.	Sharps Injury Survey 2001 Unpublished Data	Continuous

Variable Name	Operational Definition	Data Source	Variable Type
Hospitals 2001			
Needlestick and Sharps Injuries in Nurses in CA Hospitals in 2001	The California Sharps Injury Study collected the total number of needlestick and sharps injuries in all nursing staff (RN and LVN) in 2001.	Sharps Injury Survey 2001 Unpublished Data	Continuous

Statistical Analysis

Analyses for this study were conducted using SAS, version 9.2 and SPSS for Windows, version 16.0 (SAS 9.2; SPSS 16, 2007). Visual screening was performed to check for data entry errors and other discrepancies. Descriptive statistics were performed for demographic and other variables. Means, standard deviations, maximum and minimum values, frequency, percent, and measures of central tendency were performed on all variables and used as an additional check for missing data and other errors. Data were also checked for range and outliers. Extreme data values were removed if the data were determined to be logically inconsistent by two researchers. One example of this included a calculated rate of injury that was more than two times the next highest value. For this value, data entry was checked using the originally-submitted paper form. The reported data was determined to not be logically possible given the number of full-time equivalent (FTE) staff employed in this setting; hence, this value was deleted from the analysis.

Hospital characteristics and study variables were characterized using descriptive statistics including frequency, mean, median, and standard deviation. Independent sample t-tests were used to evaluate differences between participating and non-participating hospitals when the values were normally distributed. Nonparametric tests, including the Mann-Whitney U Test and the Kruskal-Wallis Test, were used when the differences were not normally distributed. The Chi-square test and Fishers Exact Test were used to evaluate study participation by ownership category and union presence. Participating hospitals were compared with non-participating hospitals using the variables included in the analyses, supplemented by other variables of interest that are typically used to describe hospitals such as measures of bed size, productive hours for all staff, and number of FTEs, for example.

Statistical analyses were conducted using two-tailed tests and 95% significance levels. Bivariate analysis among predictor variables was performed using Pearson correlations. Correlations were also performed to examine the relationship between the independent and dependent variables. Correlations among the predictors were reviewed for the presence of multicollinearity. In general, correlations greater than 0.80 indicates the presence of possible multicollinearity and correlations greater than 0.95 are indicative of a serious problem (Cohen, Cohen, West, & Aiken, 2003; Katz, 2006). A correlation matrix of all independent variables was created to assess multicollinearity. Values were checked for strength of the associations and direction. Variables that demonstrated a high degree of collinearity were evaluated for inclusion in the regression model. In the initial evaluation, Spearman Rank Correlations were used to examine associations between the continuous independent variables due to the assumption of non-normal (non-parametric) distribution. Early in the process, many variables were assessed but not adopted for the regression model. Reasons included multicollinearity among variables that logically would be related (e.g., productive hours for all staff was highly correlated with daily hospital expenses (r=.892)). Pearson values are reported, but the data were also assessed using the Spearman Rho, which produced similar and in some cases, higher values.

In this study, “Daily Hospital Expenses” demonstrated a positive correlation of .927 with “RN Productive Hours,” and .613 with “LVN Productive Hours.” Because of this, a decision was made to eliminate “Nursing Productive Hours” when evaluating Sharps Injuries in All Staff (Outcome 1). When Outcome 2 (Sharps Injuries in Nurses) was evaluated, which is the number of RN and LVN injuries divided by the number of available beds, the variable “Daily Hospital Expenses” was removed from the model and “RN and LVN Productive Hours” was used as a representative of financial and nursing variables.

Missing Data: Some data from the secondary databases were discovered to be missing. In these cases, an attempt was made to obtain the missing information, but no imputation techniques were employed. Two sources of publicly reported data were available to assist with steps to accurately complete each hospital’s reports. First, the State of California maintains information about licensed health facilities. That resource was accessed to cross-reference type of hospital, ownership, status of operation from 1997-2001, and ID numbers (California Department of Public Health, 2010). In addition, OSHPD requires an annual utilization report to be filed as well as a financial report. That data source was accessed to verify or obtain details missing in the financial report, such as a bed size or staffing parameters. In an effort to verify OSHPDs’ guidance to hospitals regarding missing data elements, the document,“ Instructions and Frequently Asked Questions for the Annual Financial Disclosure Report,” was obtained from the OSHPD website (Office of Statewide Health Planning and Development (OSHPD), 2010). To further validate information in the instructions, a telephone exchange with a staff person responsible for auditing these reports was conducted (Lohr, 2010) . Some hospitals were called to update information on union status. Of these, eight did not return calls or provide a response. Internet resources, state and national studies and reports, and other public information were used to verify ownership details, operational status, or union status. Not all hospitals submitted financial data individually if they were members of a hospital group. Hence, many financial indicators that would have been interesting to add to the regression model were not used because doing so would have resulted in a loss of many cases. This was the single biggest limitation of the OSHPD secondary dataset.

Additional Transformations and Calculations to Variables

Some variables required an additional adjustment to arrive at a more stable or accurate measurement for the model. Two variables, "RN Productive Hours" and "LVN Productive Hours," were standardized by hospital size by dividing by "100 Available Beds." In addition, the variable "Daily Expenses" was also standardized by adjusting for hospital size as above. Another variable that required additional transformation was the financial variable "Payer Mix," which is not denoted as an explicit financial value in the OSHPD files. A thorough review of the 2001 financial report showed three different categories reported by some, but not all of the hospitals across the payer types. These included Patient Days by payer, Revenue by payer, and Discharges by payer, with a total reported for each category. The payer sources included Medicare, Medi-Cal, Third Party, Indigent, and Other. For the 2001 reports, a managed-care category was added for each of the major payers to create a total of ten different payer variables. When hospital level reporting was evaluated, there were gaps in available data. Therefore, for this analysis a decision was made to use the reported "discharge days by payer" in the OSHPD Financial File as a measure of payer sources for each hospital.

Because of the reporting irregularities observed in the OSHPD database related to discharge variables, a decision was made to sum all reported types of discharges across payer types. This value was contrasted with the number of "Total Discharges" as reported by hospitals to OSHPD. The OSHPD total was found to be in excess of a million extra discharge days when compared to a manually calculated sum. For this study, a decision was made to use the calculated total instead of their reported value. Four "Payer Mix" variables were used, each representing a percent of the calculated number of discharges: Percent Medicare, Percent Medi-Cal, Percent Third Party, and Percent Other.

When the payer mix discharge percentages were entered into the Nurse Injury analysis (Model 2) high Variance Inflation Factors (VIF) were noted for several variables. This is an indication of serious multicollinearity among the payer mix variables. (Note: tolerance measurements, a reciprocal measure of the VIF, also showed evidence of multicollinearity.) The treatment of payer mix as a percentage caused these variables to be "ipsative," a phenomenon that occurs when percents or scores are used that add to a constant sum (100%) (Greer & Dunlap, 1997). The same degree of multicollinearity was not found in the All Staff analysis, which also included the three major payer sources. This difference could be explained by the larger sample of hospitals in the All Staff model as well as the larger denominator in these rates. VIF is a principal diagnostic to a measure how much the variance in the estimate of the regression parameter is inflated because another independent variable contains redundant information (S. Glantz & B. Slinker, 2001b). As stated by Glantz (2001), VIF values of four should cause concern, and VIF values of ten or greater demonstrate serious multicollinearity.

There are several methods for addressing multicollinearity including increasing the sample and deleting variables from the analysis, as examples. Increasing the sample was not feasible as the original study had been closed. Dropping variables is also problematic. Doing so may jeopardize results if variables in question were selected *a priori* based on a hypothesis about the suspected nature of the relationships between the independent and dependent variables. This was the case with regard to hospital characteristics and needlestick injuries.

Hence, a new variable called "Major Payer Source" was created from the ipsative data (the payer mix percentages). Each hospital was assessed to determine which of the four payer sources contributed the greatest amount of reimbursement in 2001. That variable was then further transformed with Medicare becoming the referent source (and major source of payment in hospitals in 2001).

Log Transformation of Injury Rates: Log transformations are used as a remedy to address outliers, failure of normality, or linearity (Tabachnick & Fidell, 2001). Transformation of either independent or dependent variables is performed when the results are non-linear, and in an evaluation of the residuals, they are also non-linear. The statistical procedure is used to "flatten out" the residual plot. The procedure may lead to an equation that better fits the assumptions in the underlying regression analysis, but it may also provide better structural insight into the process that gave rise to the data in the first place (S. Glantz & B. Slinker, 2001a). In this study, the dependent variables, injury rates in all staff and in nurses, were transformed. The log rates were used as the outcome measure in multivariate hierarchical linear regressions. The results of the hierarchical regression with reported injury rates and the log of injury rates are compared and contrasted in the results sections in Chapter 4.

Limitations. Data collection was limited to acute care licensed hospitals. Hence, the findings may be generalizable only to such hospitals in California. A second limitation relates to OSHPD data collection methods. Consolidated hospitals are able to submit combined reports to OSHPD. This means that hospital-level data needed for this study (e.g., detailed financial reports) failed to appear in the OSHPD database. Consolidated reports are common for certain financial elements, such as revenue and expenses, but utilization data (such as days of care, discharges, and productive hours) tended to be reported at the individual hospital level.

Analytical Approach

Multivariate hierarchical linear regression was performed with injury rates functioning as the dependent variable. First, all of the continuous and dichotomous variables representing hospital and market characteristics were entered into the model simultaneously. Next, the first categorical variable, ownership, was entered into the model to account for its unique contributions. In the nurse injury model, the third categorical variable, major source of payment, was entered as a third step. Multiple regression analysis was performed to assess the potential contribution of hospital demographic and financial factors, as well as population and market factors, on sharps and needlestick injuries in two groups (hospital staff and hospital-based nurses).

Chapter 4: Results

This chapter presents the results of a study focused on factors associated with needlestick and sharps injury rates in hospital-based healthcare workers in California hospitals in 2001. An overview of general characteristics of California hospitals in 2001 will be presented, followed by a description of the participating hospitals. Mean values of specific hospital variables were compared using appropriate statistical tests to assess differences between participating and non-participating hospitals. Finally, using multivariate analysis, two regressions were performed to analyze the statistically significant relationships between independent variables and the dependent variable. The first regression assessed factors associated with sharps injury rates in all staff, while the second evaluated factors associated with sharps injuries in nursing staff.

Demographic Characteristics

During the original study period, 417 general acute care hospitals were invited to participate in the Sharps Injury Study. Of those, 249 provided sharps injury data for at least one year representing 59% of the hospitals. Two hundred and nineteen hospitals submitted healthcare worker injury data to the Sharps Injury Study in 2001, accounting for 88% of the total study sample. Table 2 provides an overview of general hospital characteristics for this sample.

Hospitals in California vary greatly, a fact borne out by key descriptive characteristics. The mean number of available beds was 197.40 (SD=154.77) with a minimum of 10 and maximum of 1147. The mean number of annual Patient Discharges for the total sample was 8,136.54 (SD= 7352.33) while the average Length of Stay excluding long term care days (LOS) was 4.5358 (SD=7.35) with a range from .26 days to 60.40 days. Daily hospital expenses were reported in dollars with a mean value of $52, 468.73 (SD=$56,183) per day. The average number of nursing personnel per hospital was 265.04 (SD=286.03) with a minimum of 7 and a maximum of 2,619. The mean Case Mix Index (CMI) score was 1.086 (SD=.30; minimum 0.52, maximum 3.34), with higher numbers indicating a greater severity of illness.

Table 2. General hospital demographics for hospitals invited to participate in the Sharps Injury Study in California in 2001 (n=417)

	Mean	**SD**	**Median**	**Minimum**	**Maximum**	**N**
Available Beds	197.40	154.77	161.50	10.00	1147	408
Licensed Beds	215.40	188.46	170.00	10.00	1457	408
Staffed Beds	179.23	146.76	148.00	4.00	1147	408
Patient Days	46613.38	45494.24	35187.50	221.00	387099	408
Patient Discharges	8136.55	7352.33	6226.47	28.00	44696	408
Length of Stay	4.54	7.35	3.07	.26	60.40	405

Daily Expenses	52468.74	56183.66	32173.12	1150.72	372696	405
Case Mix Index	1.09	.29	1.03	.52	3.34	410
Productive Hours RN	368644.08	3.96	235896.27	4138.44	2777756	405
Productive Hours LVN	46110.15	45044.98	33327.57	317.00	293019	399
Average Number of Nursing Personnel	265.04	286.17	172.00	7.40	2619	393

Comparison of Participating and Non-Participating Hospitals

Hospitals were classified as participating facilities if they contributed injury data for any year that was included in the study period (i.e., 1997-2001). All hospitals that provided injury data for the study were compared to hospitals that did not contribute any data to the original study. The participant group accounted for 60% of the 417 hospitals (n = 249) while non-participants accounted for 40% of the eligible hospitals (n = 168). Table 3 provides a summary of comparisons between the two groups.

Fifteen comparisons were made between the two groups. Of those, three hospital characteristics were found to differ between the hospital groups: daily hospital expenses, productive hours for RNs, and the percent of Medi-Cal discharges. For daily hospital expenses, the mean value was higher for participating hospitals ($56, 512 vs. $46, 403, p = .032), as well as for productive RN hours (381,342 vs. 349,600, $p = .043$). Conversely, the percent of discharged patients with a primary source of Medi-Cal payment was higher in the non-participating hospitals (25.52 vs. 22.43, p=.010). One population characteristic, the percent of population over age 65, was also significant but the difference between the groups was extremely small (10.63% vs. 11.23 %, p= .006). All four of these characteristics were considered for inclusion in the final regression model.

For this study, hospital ownership was classified into three categories: non-profit, for-profit, and government and district (Table 4). Of the total sample of general acute care hospitals in California in 2001 (N = 417), 53% were non-profit hospitals, and they accounted for 57% of participating hospitals. In contrast, for-profit hospitals comprised 27% of the total sample and 20% participation in the sharps study, while government and district hospitals represent 19% of the total group and 22% participation. A cross-tabulation demonstrated a statistically significant difference among ownership categories and participation with non-profit hospitals participating significantly more than hospitals in the other two categories ($\chi^2_{(2, n=249)} =$16.05, p = <.001).

Differences in union status were also examined (Table 4). Unions were present in 47% of hospitals (n=113). A Chi-square test for independence (with Yates Continuity Correction) indicated a significant association between union status and participation in the Sharps Injury Study ($\chi^2_{(1, n=214)} = 16.56$, p=<.001).

Table 3. Comparison of participating and non-participating hospitals, Sharps Injury Study, 2001 data only: Mann Whitney Tests + *denotes variables used in regression*

Hospital and Population Characteristics	**Participating**			**Non-Participating**			**Mann-Whitney U Bold= sig**
	Mean	SD	n	Mean	SD	n	
Available Beds	199.50	144.50	245	199.42	169.46	163	.314
Daily Expenses+	56,512.33	55,880.95	243	46,403.00	56,260.0	162	**.032***
Herfindahl Index (HI) +	.0405	.038	246	.0347	.0362	136	.073
Total Discharges	8559.93	7199.31	245	7500.16	7554.19	163	.062
RN Prod Hrs+	381,342.41	369,500.00	243	349,600.00	433,520.00	162	**.043***
LVN Prod Hrs^	46,758.34	45,668.38	239	45, 120.00	44,200.00	160	.820
Length of Stay+	12.4889	34.139	245	16.296	48.7129	163	.082
Case Mix Index+	1.10	.31	247	1.0814	.2867	163	.820
% Medi-Cal Discharges+	22.43	19.77	240	25.52	19.23	159	**.010***
%Medicare Discharges+	43.55	21.85	244	47.40	19.21	161	.096
% Third Party Discharges+	25.95	22.95	242	25.52	19.23	161	.087
% Other Discharges+	9.3287	16.78	237	6.53	1.02	154	.540
% of Population over 65+	.1123	.0237	244	.1063	.0184	165	**.006****
Unemployment Rate+	5.848	3.103	244	5.789	3.046	165	.918
Per Capita Income+	32,078.59	9844.49	244	30,764.89	8164.87	165	.449

*p<.05,**p<..01

Table 4

Participation in Sharps Injury Study by ownership type and union status (n = 417)

Participation	Yes n (%)	No n (%)	Total n (%)
Non-profit*	144 (57%)	82 (47%)	226 (54%)
For-profit	50 (20%)	64 (37%)	114 (27%)
Government and district	55 (22%)	25 (15%)	80 (19%)
Union	113 (47%)	42 (26%)	155 (39%)
Non-Union	130 (53%)	120 (74%)	250 (62%)

* significant difference between ownership type $\chi^2_{(2, n=249)}$ = 16.05, p = >.001).

** significant difference between union status $\chi^2_{(1, n=214)}$ = 16.56, p=>.001).

Factors Associated With Sharps Injury Rates

Hospitals reported a mean of 26.69 sharps injuries (SD= 27.22) with 10 hospitals reporting no injuries (see Table 5). The number of reported injuries ranged from 0 to 132 during the year. Rates of injury were created by dividing reported injuries by the number of available beds for each hospital, corrected by 100. One hospital had a calculated injury rate among all staff of 129.87 injuries per 100 available beds, more than twice the rate of the next lowest rate. A review of hospital descriptive statistics indicated a skewness statistic with a non-symmetrical distribution of the means [Skewness Statistic, 4.34, Standard Error (SE). 0.164] (see Table 5). Following removal of the questionable value, the mean injury rate per 100 available beds changed from 13.38 to 12.85, and the skewness statistic dropped to 1.27, SE, 0.165. This indicates an extended tail in a positive direction. Other calculated rates were assessed using scatterplots, box plots, histograms, and plots of the residuals. Though several rates in the ≥40 injuries per 100 available beds range were identified, they were clustered closely enough to warrant continued inclusion in future analyses (Figures 3, 4).

Table 5. Needlestick and sharps injury rates in all staff, 2001 (n = 219)

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	
						Statistic	Std. Error
Injury rate in All Staff including outlier	219	.00	129.87	13.38	12.46	4.34	.164
Injury rate in All Staff excluding outlier	218	.00	57.33	12.85	9.66	1.37	.165

Figure 3.Sharps injury rates in all staff in California hospitals, 2001 with outlier included (n=219)

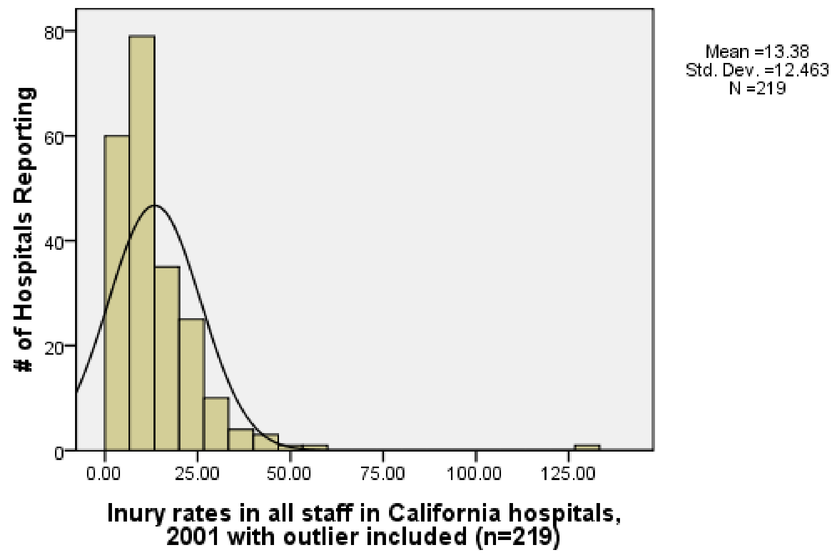
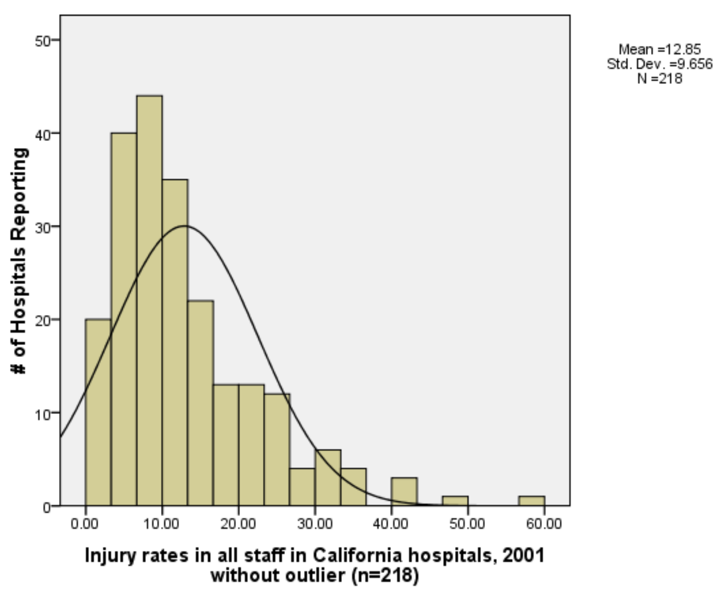


Figure 4. Sharps injury rates in all staff in California hospitals, 2001 with outlier removed (n=218).



The hospital sample remained the same for the second analysis. Most predictor variables were retained in the second analysis. However, a new variable was included: productive hours for RNs and LVNs. Productive hours are considered to most closely estimate the time spent in direct care activities (D. Harless & B. A. Mark, 2006). Analysis found that nursing productive hours were highly correlated with daily hospital expenses; thus, a decision was made to remove daily hospital expenses from this analysis.

Fewer hospitals reported sharps injuries in nursing staff (n=169) than sharps injuries in all staff (n=219). The number of injuries among nurses per hospital ranged from 0-52, with 18 hospitals reporting no injuries. The mean number of reported injuries was 10.20 (SD = 10.52). Only one hospital reported more than 50 injuries.

In this sample, injuries in nurses represented 33% of all reported injuries (Figure 5). Although there is some non-normality to this distribution, with a tail demonstrating skewness in the positive direction, the skewness statistic is 1.546. While this result is not zero, the preferred outcome, this result is not of sufficient concern to warrant further evaluation of potential outliers.

Only 168 hospitals had both numerator and denominator data available for calculating injury rates. The rate of injury among nurses in individual hospitals ranged from 0 to 35.06 with a mean injury rate of 5.47 injuries per 100 available beds (SD = 4.60). The skewness statistic for this analysis is 2.219 and demonstrates a positive tail. Again, while not centered at zero no values were deemed to be outliers (Figure 6).

Figure 5. Number of reported sharps injuries in nurses in California Hospitals, 2001 (n = 169)

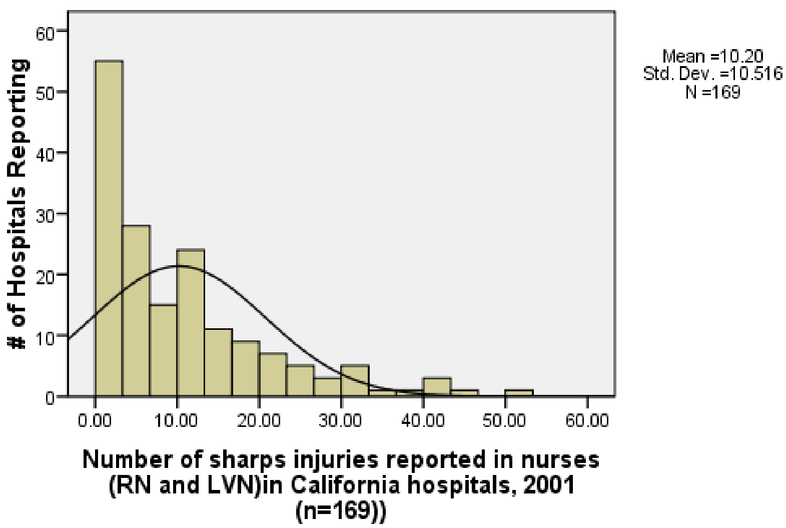
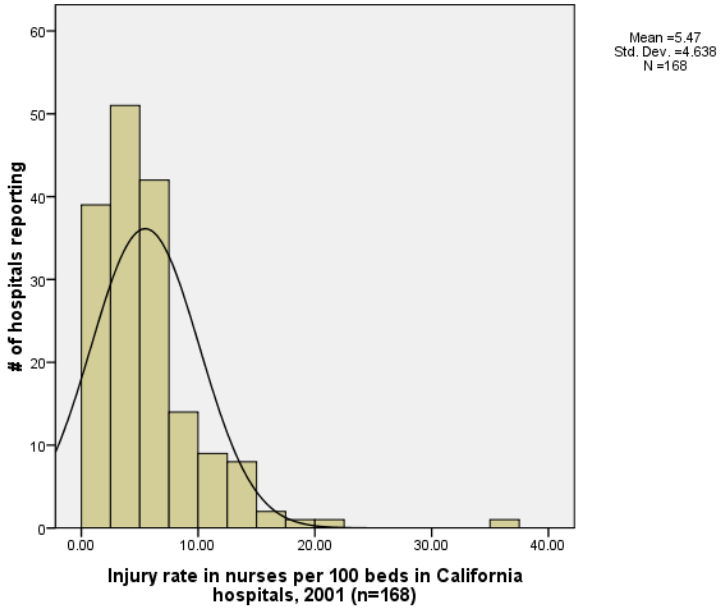


Figure 6. Rate of sharps injuries in nurses in California hospitals, 2001 (n = 168)



Correlations Among Model Variables

Tests were conducted to check for violations of statistical assumptions. In assessing correlational measures for Outcome 1, bivariate scatterplots were examined for outliers, linearity, and homogeneity of variance. Analysis of residuals was also performed. All independent variables in the model were assessed for their relationship with outcome variables for both analyses using the Pearson Product correlation coefficient. Although some correlations were below .3, a suggested threshold to assess a minimum relationship, none were over .7, which some authors recommend as a sign of multicollinearity (S. Glantz & B. Slinker, 2001; Katz, 2006). Table 6 provides a summary of the relationships between the independent and dependent variables in the model. Correlations between independent variables entered into the multiple regression analysis were evaluated by evaluating the coefficient value and the Variance Inflation Factor, with no value approaching the area of concern. An assessment of the final variables entered into the model showed no evidence of multicollinearity. Correlations were observed at levels from -.399 to .221, revealing little concern for redundancy.

Table 6. Correlations matrix of continuous variables with the dependent variable, all staff injuries (n=207)

	All Staff Sharps Injuries	Length of Stay	Case Mix Index	Daily Expenses	% Discharge Medi-Cal	% Discharge Medicare	% Discharge Third-Party	Herfindahl Index	Per-Capita Income	% Population over 65	Unemployment rate
All Staff Sharps Injuries	1	-.186**	-.062	.152*	-.040	-.348**	.190**	.099	-.017	-.106	.006
Length of Stay		1	.067	-.087	.163**	.073	-.075	.045	.072	.129**	.081
Case Mix Index			1	.225**	-.244**	.286**	.016	.089	.138**	-.016	-.149**
Daily Expenses				1	.147**	-.278**	.034	.544**	.266**	-.155**	-.147**
% Discharges Medi-Cal					1	-.397**	-.416**	-.064	-.094	-.136**	.100*
% Discharges Medicare						1	-.431**	-.125*	-.021	.157**	-.032
% Discharges Third Party							1	.213**	.132**	.002	-.038
Herfindahl Index								1	.195**	.061	-.055
Per-CapitaIncome									1	.058	-.581**
% Population over 65										1	-.099*
Unemployment rate											1

* *p* <.05. ***P* <.01.

Outliers. Outlier values for all variables were checked to determine whether injury data had been correctly coded and entered into the database. Data obtained from OSHPD was also examined for outlier values. Only one variable, injury rates in all staff, contained an outlying value. This was removed from the analysis as previously described.

Multicollinearity. In this study, multicollinearity was assessed through a correlation matrix of all independent variables. Values were checked for strength of the associations and direction. Those that demonstrated a high degree of collinearity were evaluated further. Some hospital characteristics demonstrated clear evidence of multicollinearity. For example, the correlation between the daily hospital expenses and productive RN hours was extremely high (r = .922). Likewise, the number of licensed beds was found to have a high correlation with daily hospital expenses (r = .874), and with productive RN hours (r = .801). A decision was made, therefore, to include only one representative financial variable in each model. Daily hospital expenses were selected for the purpose of evaluating injuries in all staff (Outcome 1).

Another measure of multicollinearity, the Variance Inflation Factor (VIF), was evaluated after the analyses were completed. VIF is a principal diagnostic to a measure how much the variance in the estimate of the regression parameter is inflated by the fact that other independent variables contains redundant information (S. Glantz & B. Slinker, 2001b).

High Variance Inflation Factors (VIF) were noted when the payer mix discharge percentages were entered into the Nurse Injury analysis, Model 2, indicating serious multicollinearity among the payer mix variables. The VIF values were 13.62 for Percent of Discharges from Third Party, 18.46 for Percent of Discharges from Medicare and 19.17 for Percent of Discharges by Medi-Cal.   Values over 10 indicate serious multicollinearity issues (S. Glantz & B. Slinker, 2001b). In this situation, the elevated VIF values were addressed statistically by the creation of a new variable, Major Source of Payment. Discharges for each hospital were assessed for sources of payment; the primary payer (i.e., the source with the highest percentage of discharges) was coded as the "major source." Medicare payments were the major source of funding for hospitals in this study (57%), while Medi-Cal payments were the major source of funding in 17.7% of the study hospitals, Third Party payment in 18.5 %, and Other in 5.2% of the study hospitals.

Regression Model Steps and Results

This analysis, to identify hospitals factors associated with sharps and needlestick injuries in hospital staff, reflects an exploration of both the selection of appropriate independent variables as well as a one-year cross sectional examination of hospital sharps injury rates in 2001.

To evaluate statistically significant relationships between the independent variables and the dependent variable (i.e., needlestick and sharps injury rates in all staff) multiple regression analyses were performed. The injury rates were calculated as part of the original study using SAS (SAS 9.2). Data from these files was transformed from SAS into SPSS by an independent consultant. Regression analyses and all other calculations were conducted using SPSS 16 (SPSS, 2007). Assumptions about the sample size for appropriate use of multiple regressions were met. Tabachnick and Fidell (2001) recommend a minimal sample size of 5 to 10 times the number of variables entered into the equation. Regression analyses reveal relationships among variables but do not imply that the relationships are causal, and with greater caution, are not predictive (Tabachnick & Fidell, 2001).

Outcome 1. To evaluate statistically significant relationships between the independent variables and the dependent variable (i.e., needlestick and sharps injury rates in all staff) multiple regression analyses were performed. Of the 218 reporting hospitals, 207 were included in the final model. The regression results are presented in Table 7.

A hierarchical multiple regression analysis was performed entering 12 conceptually independent variables into the equation. Eleven independent variables were entered into the equation simultaneously in Step 1. In Step 2, one categorical variable, Hospital Ownership, was entered into the equation and was represented in the multiple regression by a set of two dummy-coded variables: For-Profit vs. Non-Profit, and Government and District vs. Non Profit. Non-Profit status served as the reference group. A hierarchical analysis allowed for the independent contribution of ownership to be evaluated.

The R^2 for the overall model was .412 $_{(F13, 193)}$ = 10.395; p = <.0005), indicating that approximately 41% of the variance in needlestick and sharps injury rates in all staff was accounted for by the combination of the independent variables. The Adjusted R^2 was .372. Three of the 12 independent variables provided a significant, unique contribution to the model: Percent of Discharges by Medi-Cal (R^2 change = .051; $F_{(1, 193)}$ = 16.83, p = < .0005), Percent of Discharges by Medicare (R^2 change = .054; $F_{(1, 193)}$ = 18.01, p = < .0005), and Daily Expenses/100 Available Bed (R^2change= .1026; $F_{(1, 193)}$ =36.06, p=. <0005).

The findings of this regression indicate that hospitals that received greater levels of reimbursement in 2001 from two payer sources, Medicare and Medi-Cal, had a lower reported rate of sharps injuries among all staff in 2001. Additionally, hospitals with higher Daily Expenses had increased rates of sharps injuries among all staff in 2001.

Table 7. Regression results for sharps injuries in all staff, 2001 (n=207)

Variables	**R^2**	**Beta**	**R^2-Change**	**df**	**F**	***p***
Overall	.412			13, 193	10.395	<.0005
% Pop Over 65 years		.017	.000	1,193	0.0778	.780
Unemployment Rate		-.018	.000	1,193	0.071	.791
Per Capita Income		-.143	.011	1,193	3.629	.058
Presence of a Union		-.014	.000	1,193	0.044	.834
% Medi-Cal D/C		-.361	.051	1,193	16.835	**<.0005** **
% Medicare D/C		-.423	.054	1,193	18.0115	**<.0005** **
% Third Party D/C		-.115	.004	1,193	1.538	.216
Daily Expenses		.454	.103	1,193	36.060	**<.0005** **
Case Mix Index		-.124	.006	1,193	1.991	.160
Length of Stay(acute)		.047	.001	1,193	0.346	.557
Herfindahl Index		.011	.000	1,193	0.030	.863
Hospital Ownership			.001	2,193	0.933	.805
Prof vs. Non Prof		-.042	.000	1,193	0.4316	.512
Govt vs. Non Prof		-.004	.000	1,193	0.000	.948

* *p*<.05. ** *p*<.01.

Log Transformation of Dependent Variable All Staff Injuries

Injury rates were adjusted using a log transformation to evaluate whether the rates were sufficiently non-normal. If so, a log dependent variable would improve the analysis. An identical regression was performed using the log transformed values. The log transformation did not improve the results measurably. In fact, the R^2 for the overall model using the log transformed rate was .334 ($F_{13, 193}$) = 7.440; p = <.0005), indicating that approximately 33% of the variance in needlestick and sharps injury rates was explained by the independent variables. This represents a decrease of 19% from the original model. The Adjusted R^2 was .289. Two of the 12 independent variables provided a significant, unique contribution to the model: Percent of Discharges by Medicare (R^2 change = .015; $F_{(1, 193)}$ = 3.69; p = .038), and Daily Expenses per 100 Available Bed (R^2change= .120; $F_{(1, 193)}$ =34.93, p=.<0005). The Percent of Discharges by Medi-Cal was significant in the original regression but not in the transformed model.

The findings of the transformed regression indicate that hospitals that received greater levels of reimbursement in 2001 from one payer source (Medicare) had lower reported rates of sharps injuries among all staff. As found in the original regression, hospitals with greater Daily Expenses had higher reported rates of injury.

In a comparison of the two models, it is apparent that the transformed model does not add any additional strength to the overall findings. A comparison of the skewness statistic of the rate of injury and the log transformed rate of injury revealed little difference between them (1.372 vs. - .959). Figures 7 and 8 illustrate the regression residuals for both models, also indicating similar outcomes. Thus, it appears appropriate to accept the original regression model. When comparing the two models, the log of Outcome 1, and Outcome 1 transformed, the skewness statistic is a key measure used to determine whether a value is non-normal enough to warrant transformation (Tabachnick & Fidell, 2001). In an evaluation of the skewness statistic of each dependent variable, the initial All Staff Injury rate (Outcome 1) had a skewness statistic of 1.372. The goal is to approach a skewness measure as close to zero as possible (Tabachnick & Fidell, 2001). Two histograms are provided that illustrate the distribution of the regression residuals for both models. Following the current guidelines for transformation, and in evaluating the two revised models, it appears appropriate to accept the regression model for Outcome 1, All Staff Injuries in 2001.

Figure 7: Regression residuals for non-transformed dependent variable, all staff injuries (n= 207)

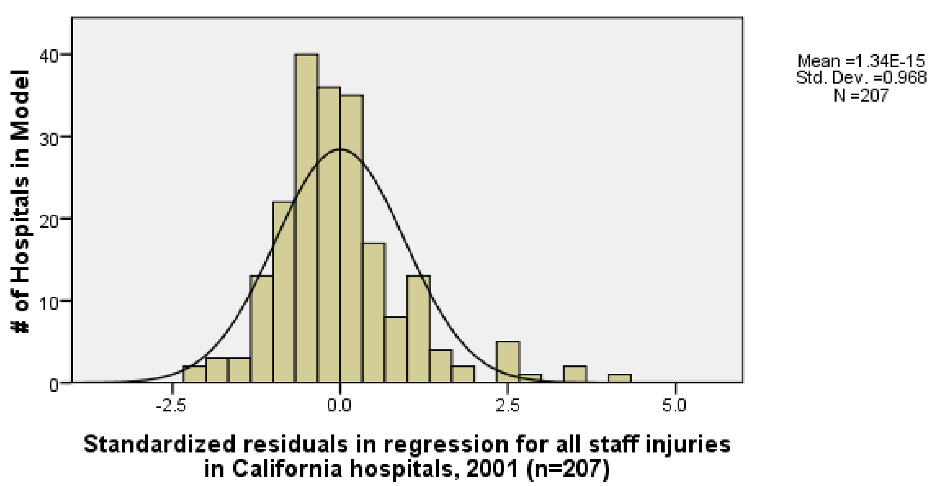
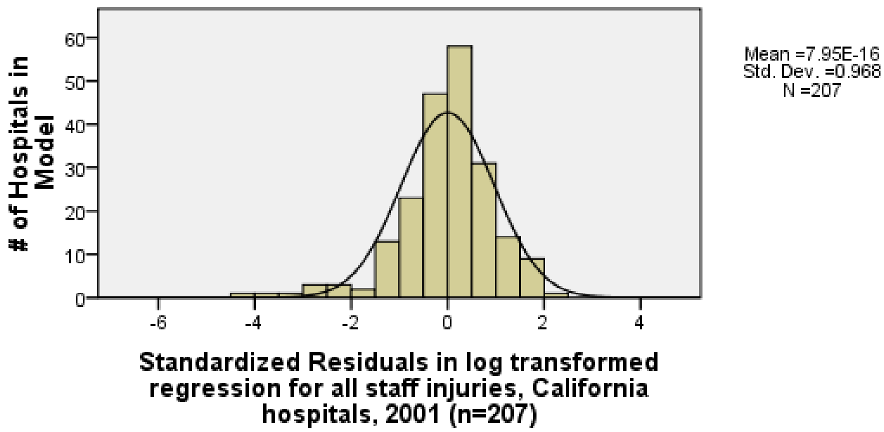


Figure 8: Regression residuals for log-transformed dependent variable all staff injuries (n=207)



Outcome 2. A second multiple regression analysis was conducted to evaluate statistically significant relationships between the independent variables and the dependent variable (i.e. sharps injury rates in nurses). The methods for this evaluation are consistent with those used for the first outcome. The second analysis was designed to replicate the procedures and assumptions used to evaluate Outcome 1 except where specifically described (deletion of independent variables representing population, income, age over 65, and unemployment rate), and selection of financial variables. Table 9 presents the

correlation matrix of continuous variables with the dependent variable, nurse injuries. The regression results for outcome 2 are presented in Table 10.

Table 8. Correlation matrix of continuous variables with the dependent variable, nurse injuries (n=160)

	Nurse Sharps Injuries	Length of Stay	Case Mix	Herfindahl Index	LVN Prod Hours	RN Prod Hours
Nurse Sharps Injuries	1.000	-.074	.013	.127	-.038	.429
Length of Stay		1.000	..623**	-.137*	.136*	-.161*
Case Mix Index			1.000	.059	-.125	.121
Herfindahl Index				1.000	-.088	.212**
LVN Prod Hours					1.000	-.075
RN Prod Hours						1.000

*p <.05. **p <.01.

Eight conceptually independent variables were entered simultaneously into the equation. In this model, daily hospital expenses (see explanation in Chapter 3) were replaced with the sum of two “financially” equivalent variables: RN Productive Hours and LVN Productive Hours. As in the evaluation of Outcome 1, the first categorical variable, Ownership, was represented by two dummy-coded variables. Non-Profit status served as the reference group. A hierarchical analysis allowed for the independent contribution of ownership to be evaluated.

The other categorical variable, Major Source of Payment, was represented by three dummy-coded variables, Medi-Cal, Third Party, and Other. Medicare as the major source served as the reference group. When the three dummy-coded variables were entered into the equation, the SPSS program issued a warning that the dummy-coded variable for "Other" had missing correlations and was deleted from the analyses. On further investigation, of the thirteen hospitals that had "Other" as the major source of payment, only two contained a report of injuries in nurses. A hierarchical analysis allowed for the independent contribution of major source of payment to be evaluated.

Table 9. Regression results for sharps injuries in nurses, 2001 (n=160)

Variables	**R^2**	**Beta**	**R^2-Change**	**df**	**F**	***p***
Overall	.284			10,149	5.917	.027
Presence of any union		.111	.0010	1, 149	2.1374	.146
Major Payer Source			.036	2, 149	3.72	.027
Medi-Cal vs. Medicare		-.059	.0028	1, 149	.5746	.450
Third Party vs. Medicare		.174	.0262	1, 149	5.494	**.020***
Case Mix Index		-.119	.0052	1, 149	1.0650	.304
Length of Stay		.112	.0052	1, 149	1.069	.303
Herfindahl Index		.032	.0008	1, 149	.1689	.681
Hospital Ownership			.006	2,149	.529	.590
Pro vs. Non Prof		-.033	.0008	1, 149	.1722	.679
Govt vs. Non Prof		-.047	.0017	1, 149	.3445	.558
LVN Prod Hours		-.007	.0005	1, 149	.0098	.921
RN Prod Hours		.493	.2043	1, 149	42.445	**.000****

* $p < .05$. ** $p < .01$

The R^2 for the overall model was .284 ($F_{10, 149}$)=5.917 ; p <.0005), indicating that approximately 28% of the variance in needlestick and sharps injury rates reported in nursing staff in 2001 was accounted for by the combination of predictor variables. Two of the variables provided a significant, unique contribution to the model. The variable Major Source of Payment uniquely accounted for 3.6% of the overall findings. The three level categorical variable had a R^2 of .036 $_{(F\ 2,\ 149\ ),}$ p.=.027, and RN Productive Hours (R^2 change= .2043; $_{(F1,\ 149)}$)= 42.225, , p <.0005. There is a difference between the three major payer source categories within the model between the major payer source Medicare and the major payer source Third Party (R^2 change = .024 $_{(F1,\ 145)}$ = 4.080, p = .045). The Adjusted R^2 was.236, which may more accurately estimate the amount of variance in the model due to the smaller sample used in this analysis.

The findings of this regression indicate that hospitals that receive greater levels of reimbursement from Third Party sources had a higher rate of sharps injuries in 2001 compared to those that received Medicare as the major source of payment. Also, hospitals with higher RN Productive Hours had higher reported rates of needlestick and other sharps injuries among nurses in 2001.

Log Transformation of Dependent Variable Nurse Injuries

Injury rates were adjusted using a log transformation to evaluate whether the rates were sufficiently non-normal, and if a log transformed variable would improve the analysis. As found in the earlier nurse injury model, it was necessary in this step to use the conceptual variable “major source” as the representative financial variable. Attempts to use the Percent of Medicare, Medi-Cal, or Third Party variables led to high VIF values among those three redundant variables.   The log transformation improved the results of the overall model. In fact, the R^2 for the transformed model was .362 ($F_{10, 149}$) = 8.451; *p* = <.0005), indicating that approximately 36% of the variance in needlestick and sharps injury rates in nurses was accounted for by the combination of the predictor variables. This represents a 17% increase in explained variance as compared to the first model. The Adjusted R^2 was .319. One of the 10 independent variables provided a significant, unique contribution to the model: RN Productive Hours (R^2 change = .253; $F_{(1, 149)}$ = 59.15; *p* = < .0005). RN Productive Hours were also a significant contributor in the original regression analysis. Unlike the original nurse injury analysis there were no findings of significant contribution by any of the “major source of payment” variable in the log transformed regression.

Chapter 5: Discussion

Healthcare providers belong to a large and fast-growing work sector in the United States (National Institute of Safety and Health, 2009). Along with the fast growth rate, rates of occupational injury to healthcare workers have also risen over the past decade (National Institute of Safety and Health, 2009) (Bureau of Labor Statistics (BLS), 2001). Sharps injuries occur from multiple sources including needles, scalpels, suture needles, and other devices capable of cutting or penetrating the skin (National Institute for Occupational Safety and Health, 2004).

While injury rates may vary among hospitals, these differences can be quantified and measured. One contributing factor may be the economics of healthcare. In the last two decades hospital environments have been in a state of constant change, and California has been at the epicenter of those changes. In addition to closures, hospitals in California (and nationally) have undergone major changes in ownership through mergers and acquisitions (Seago, Spetz, & Mitchell, 2004; Spang, Bazzoli, & Arnould, 2001). General acute care hospitals continue to close in California, with 27 reporting closures from 2001-2007 (California Healthcare Foundation, 2010). The absence of injury reports from these institutions has affected not only the sample size for this study, but also the characteristics of hospitals included in the analyses. This is a problem not only for this study, but for injury report analyses in hospitals nationwide. Health services researchers have issued a call of concern about hospital stability and capacity in California both statewide and within the distinct regions in which healthcare markets exist (Reinhardt, 2005).

Sharps Injuries in California Acute Care Hospitals in 2001

In this study, predictor variables for sharps injuries that occurred in 2001 in California acute care hospitals were evaluated for their relationship with injury rates. A range of sharps injury rates was noted among participating hospitals in both the all-staff analysis and the nursing-only analysis. These findings are consistent with other research that found needlestick injury rates may differ among hospitals based on certain characteristics such as organizational and environmental climate, staffing, hours of work, needle use, or accreditation status (L. Aiken et al., 1997; S. Clarke, 2007; Mark et al., 2007; P Stone & Gershon, 2006; A. M. Trinkoff et al., 2007). Unfortunately, not all of these specific characteristics were available in the OSHPD database. However, the variables that were available through OSHPD or collected from other sources explained 41% of the variance in injury rates in all staff and 28% of the variance in injury rates in nurses in 2001. Some of these variables have not been tested in other studies, or not in this combination, allowing for new insights into risk factors for high injury rates. In addition, other hospital databases include hospital accreditation or magnet status information, but this particular variable was not appropriate for this analysis due to the limited number of hospitals with magnet status in California in 2001. The literature did not provide any evidence that accreditation by The Joint Commission (TJC) was associated with improved healthcare worker safety. However, in 2004, OSHA and the TJC/Joint Commission Resources, Inc. TJC/JCR launched an alliance to recognize and prevent workplace hazards and to communicate that information throughout the industry (Occupational Safety and Health (OSHA), 2004). Participation in this alliance could be included as a hospital characteristic for future analyses, but was not available for the 2001 study.

Hospital characteristics

Financial:

Several factors were shown to influence needlestick injury rates in this study. For example, hospitals that received greater levels of reimbursement from Medicare and Medi-Cal payers demonstrated lower rates of needlestick injuries among all staff (Outcome 1). Hospitals with higher Daily Expenses had higher rates of needlestick and other sharp injuries among all staff. When evaluating injuries in nurses only (Outcome 2), the variable "major source of payment" was correlated with higher sharps injury rates, with the major source of payment being from Third Party sources, as compared to hospitals that receive Medicare as the major source of payment.

Daily expenses serve, in some respect, as a proxy for size, since larger hospitals will have greater expenses. Salaries and benefits represent the largest expenditure for hospitals due to their provision of services by a highly trained workforce (California Healthcare Foundation, 2007). Larger hospitals may have more managers and resource staff, and they may be able to execute a wider range of programs or interventions. This behavior is described as "slack," or the flexibility to deploy resources where needed and is generally controlled by the administrator (Feldstein, 1993). It would have been expected that the hospitals with higher daily expenses would have had more resources to spend on staffing, equipment, and education to prevent injuries, yet the injury rates were higher among all staff. From an economic perspective, all hospitals struggle to balance their production goal (care provision) while still minimizing costs (Folland, Goodman, & Stano, 2004b).

Hospitals receive 93% of their funding from patient care services (The Center for Health Affairs, 2007). In California hospitals in 2001, Medicare's distribution of net patient revenue accounted for 35% hospital income, Medi-Cal constituted 20%, Private insurance, 39%, Other, 4%, and Indigent care accounted for 2% of all revenues (California Healthcare Foundation, 2007). This formula for the payment of care creates a diversified or balanced mix of payers, which may (or may not) provide hospitals with resources that could be deployed in efforts that may reduce the risk of injury (such as safety education, or the purchase of safer devices). It is not possible without senior leader interviews to ascertain with certainty how resources were invested. Hence, it is conceivable that funding patterns may play a role in rates of sharps injury, though the mechanism for this is not totally clear. However, trends in healthcare financing warrant careful attention, and questions persist as to whether healthcare facilities have resources adequate to invest in needed education and safety equipment given the demands of the market and the over arching influence of the production function (Buerhaus, 2009; Feldstein, 1993).

Case mix index (CMI). Although CMI was not found to be associated with sharps injury rates in this study, patient acuity or severity of care are factors that have been associated with increased other types of injury in hospital nursing staff (Mark et al., 2007; Menzel, 2008). There may be a relationship between patient severity (CMI) and RN Productive Hours, which were associated with higher injury rates in nurses. Patient severity has been documented to cause nurses to encounter time-sensitive situations that require immediate action (Mark et al., 2007). In previous research, it was noted that patients' needs, and a desire to not delay patient treatment, may outweigh the perceived benefits of adhering to safety precautions among nursing staff (Williams, Campbell, Henry, & Collier, 1994). Nurses consistently identify increased work complexity, which is often but not exclusively related to patient severity, as a factor that may lead to time limitations and other work hindrances that affect adherence to safe needle precautions (Ferguson, Waitzkin, Beekmann, & Doebbeling, 2004).

Staffing. In the analysis of injury rates in all staff, productive nursing hours were not used in the model. This variable was highly correlated with hospital daily expenses, and would not have been the best variable given that not all injuries were sustained by nurses. However, in Outcome 2, injury rates in nurses, there was a positive association between RN Productive hours and higher injury rates, but this same result was not found for LVNs. This finding may be due to the amount of highly technical care provided by RNs, while other personnel, such as the LVN, may be caring for less acute and complex patients and may have less exposure to sharps. It could also be a structural finding since there were considerably fewer LVN hours than RN hours in the hospitals in 2001. Other health service researchers have verified that nurse staffing trends are affected by levels and types of funding and therefore further investigation is needed to evaluate the relationship between overall reimbursement levels, payer mix, and staffing as they relate to sharps injuries (Harrington, Swan, & Carillo, 2007; Needleman, Buerhaus, Stewart, Zelevinsky, & Mattke, 2006; P. Stone et al., 2007).

Analyses for this study included data from 2001 only and reflect nursing hours and expenses prior to implementation of the minimum nurse to patient ratios in California (Coffman, Seago, & Spetz, 2002; Spetz, Seago, Coffman, Rosenoff, & O'Neil, 2000). Nursing research after implementation of the ratios in 2004 demonstrated less variation in nurse to patient staffing patterns and lower patient to nurse ratio, as required by law (Burnes-Bolton et al., 2007). Future hospital and unit level analysis in California may detect differences in RN and LVN expenses and hours of care. It will also make hospitals more similar and comparisons of productive hours before and after implementation of the ratio law less reliable.

The Herfindahl Index (HI) or measure of competition. This study found no association between the HI and sharps injury rates for either outcome. In other health services research, the HI has been found to be associated with reimbursement rates, resident case mix, and RN staffing hours (Harrington et al., 2007). There is a large body of literature on the relationship between hospital reimbursement, costs, case mix, and competition. How these issues may relate to staffing injuries is not clear, however, and needs to be addressed in other research *(Morrisey, 2001; P. Rivers & Sejong, 1999; Rogowski, Jain, & Escarce, 2007; Santerre & Adams, 2002).*

Population Characteristics. No associations were found between the three patient population characteristics (percent over age 65 years, per capita income, and unemployment rate) in California counties in Outcome 1, and they were deleted from the analysis of Outcome 2. Hospital and long-term care research has found relationships among these variables in relation to resource utilization and percent of care reimbursed by Medicare or Indigent sources. It had been theorized that these characteristics could be related to staff injuries in an indirect manner. However, such a relationship was not found in this study, nor has such an association been found in other hospital injury research.

As previously discussed, an analysis by geography (rural and urban) may be worth exploring in the context of sharps injuries. Other researchers have found location to be associated with the likelihood of injuries in hospital based healthcare injuries. It may also be associated with sharps injuries in home care workers. However, location was not tested in this study (R Gershon, 2008; Glenn & Ramsey, 1995; Mark et al., 2007).

Unions. In this study, no documented relationship was found between union presence and rate of sharps injury. There is some evidence in the literature that unions had a significant positive effect on workplace safety through their support for the passage of state and national bloodborne pathogen protections (Lipscomb & Borwegen, 2000; Muraskin, 1995). Unions serve as a powerful advocate for workers and workplace health and safety. Policy theorists suggest that such coalitions are at work during the process of policy change (Sabatier & Jenkins-Smith, 1999; Schlager & Blomquist, 1996). Because of union activity in California and union advocacy regarding sharps injury prevention, a relationship between union presence and lower injury rates is plausible. Since 1999, however, federal and state laws have mandated safer needle use practices. Since this study analyzed data only from 2001, it is possible that hospitals may have already implemented safer needle practices, thus negating the effect of union activity (National Institute for Occupational Safety and Health, 2009; Needlestick Safety and Prevention Act of 2000," 2000).

Study Characteristics

Strengths. This study was unique in that it tested theoretically plausible variables to examine sharps injury rates in California healthcare workers. The process of testing and reporting the results of a theoretical model may contribute to the knowledge necessary for effective health and safety interventions in the future. Reduced injury and illness can also be a positive economic outcome for employers, the employees, and the nation. Hospitals that reflect characteristics that are associated with greater injury rates may be able to employ additional preventive measures or strategies to reduce the likelihood of injury.

The concept of studying occupational injury in a hospital setting is not new. Previous health services research has demonstrated differences in injury rates at patient level outcomes (cost, quality of care, safety, and mortality rates) based on hospital characteristics (Burnes-Bolton et al., 2007; Harrington et al., 2007; Needleman et al., 2006). Fewer studies have evaluated staff injuries using a combination of hospital, financial, market, and population characteristics (S. Clarke, 2007; Mark et al., 2007).

Strength of this study was the relatively high response rate data arising from a survey. Overall, 59% of the eligible hospitals submitted reports during the survey period. The rule-of-thumb for mail survey response rates are generally in the 20% estimate, with mail surveys usually having a lower response rate than face-to-face or phone interviews, dependent on the type of follow-up and subject contacts (Groves et al., 2004).

This is one of very few (if not the first study) that explored the predictors of sharp injury rates for all staff and nurses and found that different factors influenced injury rates in all staff versus nurses working in the same hospitals at the same time.

Publically available datasets, such as OSHPD and ARF, were incorporated into the investigator initiated research data to explore contributing factors to the sharp injury rates. Research that uses publically available data is both a creative and cost effective way to address research questions.

Limitations. All of the data used in this analysis were existing data collected either for the Sharps Injury Study or for other studies or uses (such as the OSHPD or ARF). As a whole, the dataset could be classified as secondary data (Hulley et al., 2001). Although secondary data sources come readily available, there are limitations, some of which were realized in this study and reviewed in Chapter 3.

First, almost all of data sources used in this study contained missing data. The most common source of missing data was the OSHPD financial file. This limitation was overcome by cross-referencing information with other available data reports. For example, a few hospitals that had consolidated with a “parent” hospital no long submitted hospital level data to the OSHPD Financial Report, but continued to submit utilization and staffing information in the OSHPD Utilization report (Office of Statewide Health Planning and Development (OSHPD), 2010). In addition, ownership status, operational status, and other distinguishing hospital level data was validated using resources such as the facility licensing agency (California Department of Public Health, 2010). This strategy is consistent with the recommendation that when possible, a researcher use multiple data sources to cross-check for consistency (Hulley et al., 2001).

Second, while the integrity or accuracy of data entered by hospitals is of concern to outside reviewers, there are ongoing efforts by OSHPD to assure accuracy of the data (USC Center for Health Financing, 2010). Other researchers have used California data in their studies even as they caution that the data is not without error, especially when using it as a validation source (D. Harless & B. Mark, 2006). In spite of these concerns, health service researchers who evaluate large national data sets have identified California and the OSHPD information as a source by which to validate other staffing studies.

Generalizabilty of study results. Data for the original sharps injury study was collected on a state-wide basis with a 59% response rate overall. Characteristics of participating and non-participating hospitals were compared with minimal differences noted. However, results of this study may not be generalized to non-acute hospitals due to differences in staffing, organization, and payment sources. Nevertheless, the results provide substantial information about sharps injury rates in California facilities.

As the most populous state, California has the largest number of hospitals of any other in the United States (American Hospital Association, 2000; Office of Statewide Health Planning and Development, 2006; USC Center for Health Financing, 2010). Hospital ownership includes large multi-hospital corporations both for-profit and non-profit. In addition, California has a higher proportion of unionized nurses (approximately 43%) and is the only state with a legislatively mandated nurse to patient ratio (Chapman et al., 2009; Coffman et al., 2002; Spetz et al., 2000). California is also unique in that it has a large amount of up-to-date publicly reported healthcare data that is readily accessible. These differences may make replication of the study results described here difficult in other states.

Significance and Implications

As widely reported, hospitals are dangerous places for workers. In an evaluation of the percent of all reported occupational injuries in 2001 nurses accounted for 33% of the injuries (National Institute of Safety and Health, 2009). Although that percent was found to be lower for nurses than previous surveillance reports, rates have begun to increase again in recent years (Massachusetts Department of Public Health Occupational Health Surveillance Program, 2010).

While hospitals differ in many respects, the more that is understood about factors that place workers at risk or protect them from work related injury, the more likely that effective interventions can be put in place. Because of the impact of new U.S. regulatory laws, injuries from needles and other sharps has declined (but not disappeared) in some product lines or settings, but still presents threats to all workers, especially those working in emergency and surgical settings and home healthcare (R. Gershon et al., 2009; J. Jagger, Perry, Gomaa, & Phillips, 2008; Leiss et al., 2006). Nonetheless, more must be done to reduce the risk of injury from sharps devices (Clark, 2009; National Institute of Safety and Health, 2009). The preliminary findings of this study indicate that hospital and regional characteristics may be associated with the rate of occupational injury from needlesticks and other sharps. This first effort to evaluate the theory and test the model warrants further exploration. A critical priority exists to continue to modify the model so that it can be reliably used to assess the potential contributors to needlestick and sharps injuries in all staff and among nurses.

The meaning of injury reports is often debated. Elevated injury rates can mean more than one thing (robust reporting, or safety issues) and it is imperative that researchers are cautious when drawing conclusions about events. Safety culture and climate have a direct relationship to reporting rates and must be factored into future analyses (Kramer & Schmalenberg, 2008; Lake & Friese, 2006).

All workers in any healthcare setting are at risk for injury from needlesticks and sharps. Prevention efforts must be targeted and effective across the entire setting and should as well include issues of safe disposal to protect downstream workers and communities from accidental injury. Nursing remains the workforce most at risk of sharps injuries due to their constant presence in all levels of care and their frequent needle and sharp use (Beekmann et al., 2001; Centers for Disease Control and Prevention, 2008; Chen & Jenkins, 2007; Leigh, Wiatrowski, Gillen, & Steenland, 2008; Lipscomb et al., 2009). This presents a challenge across the domains of education, service, and administration. First, educational implications include advocacy-based education for nurses as to the health and safety of their chosen profession and how to best promote optimal settings. Promoting strong research agendas that can be translated into practice must be prioritized to help protect nurses from occupational injury.

Second, service organizations have a special duty to promote the highest standards of safety and health in their workplace. Organizations that represent hospital staff and nurses can act collectively to promote safer work settings. All staff should be fully informed about workplace risks and prevention strategies, and they should be encouraged to adhere to safer work practices. Nurses, physicians, and other hospital workers may belong to professional associations, specialty associations, trade associations, or unions and may find opportunities for education and advocacy through those relationships. All workers deserve a safe and healthy workplace, and they advocate for themselves and their patients and families as they move the safety agenda from theory to practice.

Finally, administrative nurse leaders have the opportunity in their organizations to ensure that all efforts to address patient safety are closely aligned and consistent with worker health and safety. Decisions regarding resource allocation, supply purchases, and educational activities can be aligned with a health and safety agenda in partnership with those in service. The Magnet Recognition Program in over 300 U.S. hospitals created the path toward a practice model of partnership, with a hoped for improvement in patient care and positive workplaces (McClure & Hinshaw, 2002). At this time, there are 21 hospitals in California that have obtained the Magnet recognition, with most of them receiving that accreditation after 2003 (American Nurses Credentialing Center, 2010). Whether the recognition and the efforts that are involved for a facility to apply also benefit the working environment and safety of nurses in those hospitals is yet unanswered, although the most recent research from the University of Maryland may indicate otherwise (A. Trinkoff et al., 2010).

Occupational health nurses are in a unique role to further test theories and develop knowledge about safe practices and injury prevention strategies. Typically they are at the front line of the workplace and are critical advocates for safer equipment, educational services, and intervention programs. Opportunities may exist to link efforts to improve patient safety with efforts to improve safer workplaces for healthcare workers. The current tools and strategies have many areas of overlap and a harmonized approach would likely lead to improvements across worker, patient, and community populations.

Conclusion

Sharps injury rates have improved somewhat from the earliest reports in the 1980s. In spite of the good news, recent reports show that injuries continue to happen throughout the healthcare workforce even when staff have access to safer devices (Massachusetts Department of Public Health Occupational Health Surveillance Program, 2010). What is important at this juncture, ten years after passage of the Needlestick Safety Act ("Needlestick Safety and Prevention Act of 2000," 2000) is to carefully examine the current state of injuries and their patterns and continue to improve the workplace for all healthcare workers.

Understanding how, why, and when staff are injured across the full spectrum of occupational injuries is a significant undertaking. Testing and perfecting new theoretical models will allow for a richer understanding of factors that might be associated with injury and, as a result, the countervailing forces that might lead to injury reduction.

Hospitals are complex. The well-built hospital design can protect staff and support them to provide safer care (Rechel, Buchan, & McKee, 2009). Therefore, it is imperative that healthcare leadership make the health and safety of all who enter the doors of hospitals their priority. Occupational health and policy researchers can provide essential advice to healthcare leaders to aid them in making the best decisions to achieve the fine balance of between good economic practices and injury prevention.

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School of Nursing
University of California San Francisco

Bloodborne Pathogens Standard Project

Sharps Injuries:
California Health Care Facilities and Agencies

Please complete the table below for your facility for the calendar years 1997-2001. *If you are not sure of an answer, please give us your best estimate.*

Number of Sharps Injuries	Please report only injuries involving sharps contaminated with blood or body fluids				
For the calendar year, please provide the following estimates	**1997**	**1998**	**1999**	**2000**	**2001**
1. **Total Number of Reported Sharps Injuries** from all types of needles and devices, such as syringes with needles, suture needles, lancets, etc					
2. **Number of Sharps Injuries in Registered Nurses, (RNs)**					
3. **Number of Sharps Injuries in Licensed Vocational Nurses, (LVNs)**					
Number of Employees	**The section below is optional. If FTE Numbers are not readily available please disregard.**				
4. **Number of full-time equivalent (FTE) Registered Nurses, (RNs)** on your staff during each calendar year.					
5. **Number of full-time equivalent (FTE) Licensed Vocational Nurses, (LVNs)** on your staff during each calendar year.					

Please use the Business Reply Envelope provided, or:

Date Due: March 8, 2002

•**Mail directly to:** Marion Gillen, Project Director
UCSF School of Nursing
Department of Community Health Systems
UCSF Box 0608/2 Koret Way
San Francisco, CA 94143-0608

•**Or Fax to: (510) 622-4310**

For more information: (510) 622-435

Appendix 2

1.

HOSPITAL DESCRIPTION

Hospital DBA Name ______________________________ Report Period End ____________________

Line No.	MISC. INFORMATION	(1)	TYPE OF CONTROL (one only)	(2)	TYPE OF CARE (one only)	(3)	Line No.
5	Licensed Beds (End of Period)		Church		Short-Term - General		5
10	Available Beds (Average)		Non-Profit Corporation		Short-Term - Childrens		10
15	Staffed Beds (Average)		Non-Profit Other		Short-Term - Psychiatric		15
20	HSA No.		Investor - Individual		Short-Term - Specialty		20
25	If Designated Trauma Center		Investor - Partnership		Long-Term - General		25
30	Indicate Level (1, 2, or 3)		Investor - Corporation		Long-Term - Childrens		30
35			State		Long-Term - Psychiatric		35
40			County		Long-Term - Specialty		40
45			City/County				45
50			City				50
55			District				55
	GOVERNMENT PROGRAMS	(1)	PREPAID PROGRAMS	(2) - No. of Each Type	24 HR. ON PREMISES COVERAGE	(3)	
60	Medicare		Hospital Based		Emergency Services		60
65	Medi-Cal		Parent Organization Based		Psychiatric ER		65
70	Crippled Childrens		State Contracts		Physician		70
75	Short-Doyle		Federal Contracts		Pharmacist		75
80	CHAMPUS		Medical Foundation Contracts		Operating Room		80
85	County Indigent		Commercial Plan Contracts		Laboratory Services		85
90	Other (Specify)		Other (Specify)		Radiology Services		90
95					Anesthesiologist		95
100							100
105							105

ACTIVE MEDICAL STAFF PROFILE - MD's, DO's, Podiatrists and Dentists (Enter No.)

		HOSPITAL BASED			NON-HOSPITAL BASED			RESIDENTS/FELLOWS (Enter FTEs)		
Line No.	CLINICAL SPECIALTY	Board Certified (1)	Board Eligible (2)	Other (3)	Board Certified (4)	Board Eligible (5)	Other (6)	Residents (7)	Fellows (8)	Line No.
110	Aerospace Medicine							.	.	110
115	Allergy and Immunology							.	.	115
120	Anesthesiology							.	.	120
125	Cardiovascular Diseases							.	.	125
130	Child Psychiatry							.	.	130
135	Colon and Rectal Surgery							.	.	135
140	Dental							.	.	140
145	Dermatology							.	.	145
150	Diagnostic Radiology							.	.	150
155	Forensic Pathology							.	.	155
160	Gastroenterology							.	.	160
165	General/Family Practice							.	.	165
170	General Preventative Medicine							.	.	170
175	General Surgery							.	.	175
180	Internal Medicine							.	.	180
185	Neurological Surgery							.	.	185
190	Neurology							.	.	190
195	Nuclear Medicine							.	.	195
200	Obstetrics and Gynecology							.	.	200
205	Occupational Medicine							.	.	205
210	Oncology							.	.	210
215	Ophthalmology							.	.	215
220	Oral Surgery (Dentists Only)							.	.	220
225	Orthopaedic Surgery							.	.	225
230	Otolaryngology							.	.	230
235	Pathology							.	.	235
240	Pediatric-Allergy							.	.	240
245	Pediatric-Cardiology							.	.	245
250	Pediatric-Surgery							.	.	250
255	Pediatric Medicine							.	.	255
260	Physical Medicine/Rehabilitation							.	.	260
265	Plastic & Reconstructive Surgery							.	.	265
270	Podiatry							.	.	270
275	Psychiatry							.	.	275
280	Public Health							.	.	280
285	Pulmonary Disease							.	.	285
290	Radiology							.	.	290
295	Therapeutic Radiology							.	.	295
300	Thoracic Surgery							.	.	300
305	Urology							.	.	305
310	Vascular Surgery							.	.	310
315	Other Specialties							.	.	315
320	TOTAL							.	.	320

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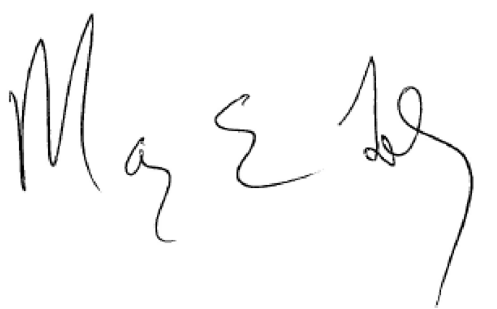

December 24, 2010

Author Signature   Date