Systematic View on NeedleStick Injuries

by

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Submitted to the System Design and Management Program on May 25th 2017 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Engineering and Management

Abstract

Each year, 385,000 needlesticks and other sharps-related injuries are sustained by hospital-based healthcare workers in U.S. (CDC, 2015). Out of the overall sharps injuries, approximately 67% are caused by needlestick devices ("CDC: Stop Sticks, Sharps Injuries," 2013). Numerous pathogens can be transmitted through needlestick injuries, but the three most common pathogens are Hepatitis B, Hepatitis C, and Human Immunodeficiency Virus.

There are processes in place to reduce needlestick injuries such as work-practice control, engineering control, personal protective clothing and equipment, employee training, etc., but they have not eliminated needlestick injuries.

The purpose of this thesis is to investigate the systematic causes of needlestick injuries in Massachusetts hospitals. System thinking process is used to define the needlestick system, interaction between stakeholders and see how injuries affect the needlestick system. System Dynamics model is also used to illustrate the pathway of the root causes of needlestick injuries.

By using system thinking, current literature, stakeholder interviews, and knowledge from shadowing at one of the reputable hospitals in Boston, a systematic solution is proposed. The proposed solution addresses the root causes of needlestick injuries: professional pressure, high patient load/long hours, and patient-centric safety culture. The proposed solution also includes methods to address underreporting.

Professional pressure and high patient load is addressed by creating programs that focus on improving self-care and reducing level of fatigue for the healthcare workers. In order to change the patient-centric safety culture, to patients *and* healthcare workers focused safety culture, the current prevention methods are reiterated. Furthermore, programs to create awareness of needlestick injuries, which forces doctors and nurses to consciously think about needlestick injury safety is proposed. An example is given of sharps injury prevention in surgeon's "time-out" checklist, similar to what is used at the Boston hospital.

Finally, to address underreporting, programs to provide quick and easy reporting process are proposed for the healthcare workers. An important complement to the reporting system is a safety culture, where the healthcare workers do not feel fear of reporting due to repercussion on their jobs.

A holistic solution is needed for a complex problem such as needlestick injuries. Only with a systematic solution that focuses on all of the root causes of needlestick injuries can they truly be reduced to a negligible amount.

Thesis Supervisor: Joan S. Rubin
Title: Executive Director, System Design & Management Program

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Acknowledgement

First, I would like to thank my boyfriend, *Kerry*, who have been through the thesis process with me every day. He not only provided me with support and understanding, but truly understood what it takes to write a thesis. I went into the thesis process thinking it would be technically difficult, but what I did not anticipate is the mental and emotional strength it takes to write a thesis. I spent majority of my day with myself, while writing this thesis, and it has taught me not only about needlestick injuries, but self-discipline and mental toughness. To do the same thing over and over again for day-in and day-out, takes a lot out of you, and when I was weak and drained, my boyfriend was there to pick me up.

Next, I would like to thank my MIT family (Ashley, Dr.T. and Harding) who I saw every day and knew what each other were going through.
Ashley: Thank you always being the yin to my yang. You are polar opposite of me, and you keep me sane and calm, while I am losing my mind, and vice versa. I enjoyed our Fridays after our 7:30am workout and spending hours after in E40 conference room writing thesis and venting.
Harding: Thanks for being Harding and just saying the most ridiculous things. It was good seeing you at Martin Trust and vent to you, while you remain calm (on the outside).
Dr.T.: Thank you for thesis topic and thank you for being a pain half the time and bringing me chocolate chip cookies the other half. Thank you for providing endless entertainment with your stories and free medical consultations.

Next, I would like to thank my family. My mom, my dad, my sister, who have always been there for me. I love you and thank you for always supporting me through all the journey in my life, including MIT. I would also like to thank my "extended" family. There are more than 20 people, so I won't list everyone, but thank you for always being you and every time I see you guys, I feel at home and just truly happy.

I would also like to thank two family friends, who are nurses, *Melissa* and *Sarah*.
Melissa: Thank you for always picking up the phone and explaining medical jargon. Not being from medical industry or having any medical background, you explaining the basis things about sharps, was so helpful.
Sarah: Thank you for helping me with all the contacts (interviewees) and giving me your time and being supportive of the topic.

My two best friends, who have been there for me for more than 12+ years. *Maria* and *Laura*: I am just grateful I have you two in my life. Even though I physically see you guys once every year, the fact that we talk once a week (or more) on the phone and we are still good friends, is something I feel very lucky to have.

I would also like to thank my advisor, *Joan*. Thank you for giving me the time every week. I know other students who saw barely saw their advisors and I am very thankful that you were committed time once a week for me. Thank you for not only committing the time, but brainstorming ideas, helping me find interviewees, and giving me a push when I needed one.

I would like to thank my interviewees. I cannot disclose their names, but *Mr. A.* (OSHA Director), *Dr.M.,* the *nurse practitioner*, and the *nurse* that I shadowed with. Thank you for the time you gave me, and all your inputs. Without your feedback and inputs in the interview, my thesis would be truly incomplete.

Finally, this is a weird one, but I honestly could not have done it without this, The Breakfast Club 105.1 (podcast). I spent the last two and half months writing this thesis, day-in and day-out. *Breakfast Club* (DJ Envy, Angela Yee, and Charlemagne da God), their humor with combination of daily news and interviews eased my mind between travel from home and school. So, thank you!

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Abbreviations

HCW	Healthcare Workers
SED	Safety Engineered Device (same as SESIP)
SESIP	Sharps with Engineered Sharps Injury Protections (same as SED)
MDPH	Massachusetts Department of Public Health
NaSH	National Surveillance System for Health Care Workers
Percutaneous Injuries	Percutaneous means "made or effected through the skin"
Intramuscular Injection	Injection given at 90 degrees to the surface of the skin
Subcutaneous Injection	Injection given at 45 degrees to the surface of the skin
Intradermal Injection	Injection given at 10 to 15 degrees to the surface of the skin

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I. Introduction

Needlestick injuries are injuries sustained by healthcare workers when they puncture their skin with a contaminated needle previously used on a patient. Each year 385,000 needlesticks and other sharps-related injuries are incurred by hospital-based healthcare workers (CDC, 2015). Out of the overall sharps injuries, approximately 67% are caused by needlestick devices ("CDC: Stop Sticks, Sharps Injuries," 2013). Numerous pathogens can be transmitted through needlestick injuries, but three most common pathogens are Hepatitis B (HBV), Hepatitis C (HCV) and Human Immunodeficiency Virus (HIV). The risk of transfer of these pathogens range from 6-30% for HBV for unvaccinated health care workers, 1.8% for HCV and 0.3% for HIV ("CDC: Frequently Asked Questions Bloodborne Pathogens Occupational Exposure," 2013).

There are processes in place to reduce needlestick injuries such as work-practice control, engineering control, personal protective clothing and equipment, employee training, medical surveillance, hepatitis vaccinations ("Safety and Health Topics | Bloodborne Pathogens and Needlestick Prevention | Occupational Safety and Health Administration," 2017).

However, the current prevention methods are not reducing needlestick injuries to a negligible amount. This thesis focuses on the question:

Why are needlestick injuries not eradicated with the current prevention methods?

Problem Statement

To propose a systematic solution for needlestick injury reduction

By investigate the root causes of needlestick injuries in Massachusetts hospitals

Using current literature, stakeholders' interviews and a system dynamics model

Methods

Existing literature research was used to create a needlestick system, identify the primary stakeholders and their interactions, see how needlestick injuries affect the system and discover the root causes of needlestick injuries.

Interviews were then conducted with primary stakeholders such as doctors, a nurse practitioner, and OSHA Director of Occupation Health all from Boston, Massachusetts. Furthermore, a nurse from medical surgical unit from one of the prestigious hospitals in Boston, Massachusetts was shadowed to gain deeper understanding of underreporting, training and patient-centric safety culture and understand the best practices on needlestick injury prevention methods. Using literature research, interviews, and the discussion from the shadowing, a systematic solution was proposed that will tackle the root causes of needlestick injuries.

II. Background

Needlestick injuries are injuries sustained by healthcare workers when they puncture their skin with a contaminated needle. The range of healthcare workers with potential exposure is broad and includes nurses, doctors, residents/interns, technicians, housekeeping personnel, food services personnel, dental staff, EMTs, etc. (Laramie MPH, Davis Sc.D, Firsova MA, Laing BS, & DeMaria Jr. MD, 2007). However, the primary stakeholders affected by needlestick injuries are nurses, doctors and residents (Laramie MPH et al., 2007) since they are responsible for the majority of clinical interventions with patients.

Needlestick injuries are a subset of the overall sharps injuries category (see Figure 1). The broader category of sharps injuries include injuries caused by needles, scalpels, lancets, razor blades, glass or any object that can cut through the skin ("Needlestick and Sharps Injuries : OSH Answers," 2014). This thesis focuses primarily on needlestick injuries as they comprise 67% of all sharps injuries ("CDC: Stop Sticks, Sharps Injuries," 2013); however, the terminology "sharps injuries" is used in this thesis when representing data taken from reports that used sharps injuries for data collection.

Using the literature research, the impact of needlestick injuries on health, cost, safety engineered devices and prevention methods are discussed in this chapter.

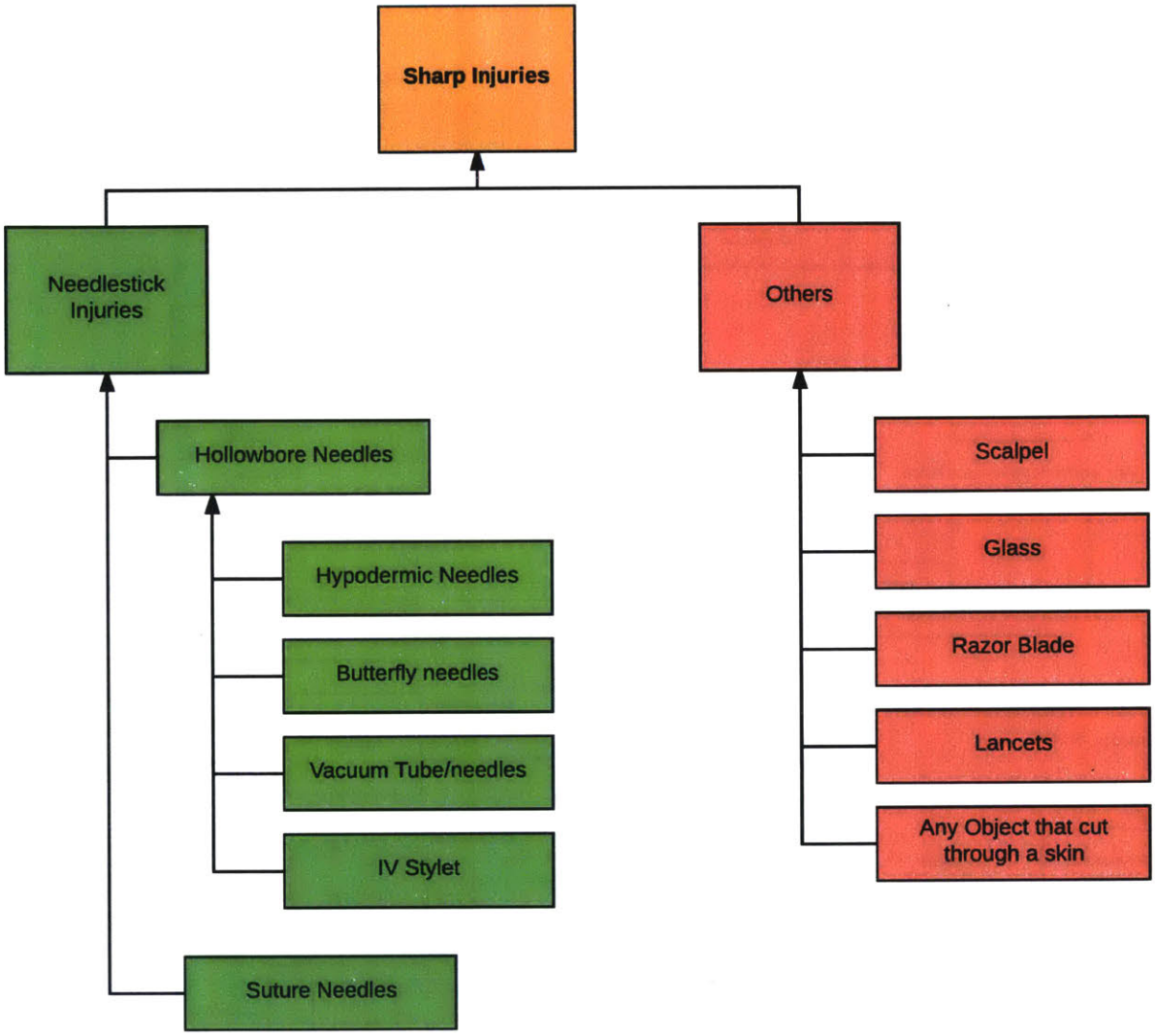

Figure 1: Sharps Injuries Decomposition

Stakeholders Analysis

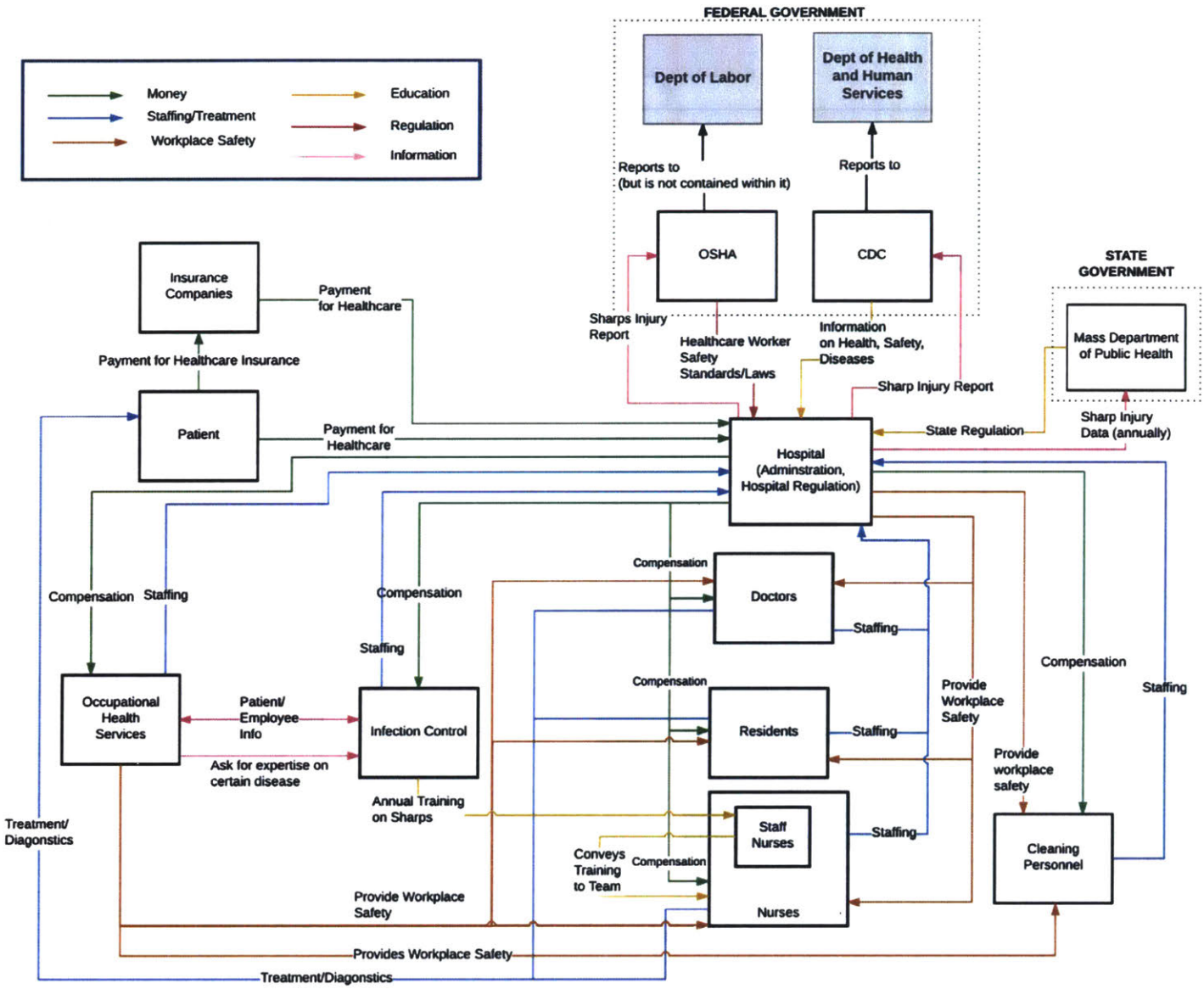

Figure 2: Stakeholder Analysis for Needlestick Injuries

Primary Stakeholders

The stakeholders that are affected by needlestick injuries are nurses, doctors, residents, cleaning personnel, other mental or dental staff and supporting staff (such as food and linen

department personnel). However, the primary stakeholders are the nurses, doctors and residents. According to Centers for Disease Control and Prevention, nurses sustained the highest percentage of injuries (CDC, 2015).

From reports published by Massachusetts Department of Public Health, the highest injuries sustained were by physicians at 39% and nurses at 36% from 2013 data ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016).

However, in that data, the categories were broad. 'Nurses' category accounted for nurses, nursing students, nurse assistants, etc. and 'physicians' category accounted for attending physicians, residents/interns, surgeons, radiologist, etc. Within the 'physicians' category, 14% out of the 39% experienced needlestick injuries were sustained by interns/residents, 11% were attending physicians, 5% are fellows, and rest identified in that category have low percentages.

In contrast, within the 'nurses' category the majority of clinicians experiencing injury were nurses (RN/LPN). They account for 31% out of the 36% who experienced needlestick injuries. Therefore, even though the 'physicians' category has the highest percentage, nurses, especially RN and LPN are the ones affected most frequently by needlestick injuries.

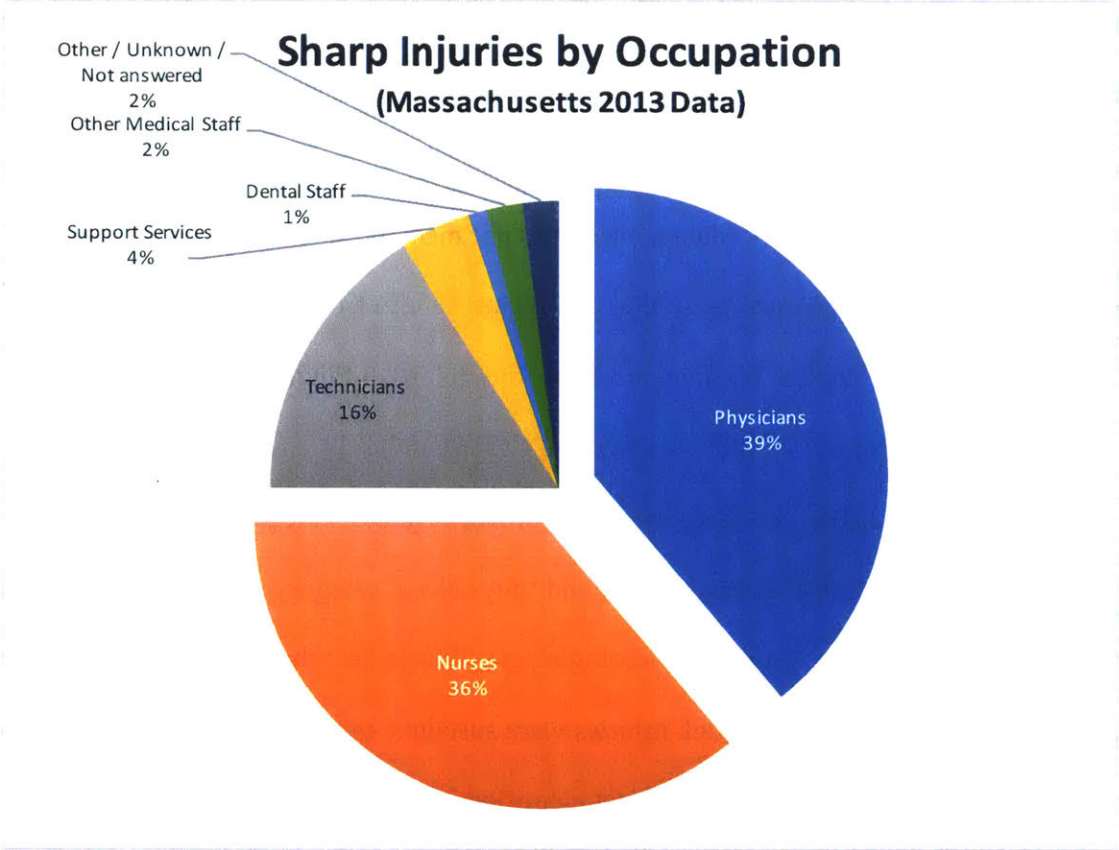

Figure 3: Sharps Injuries in Massachusetts by Occupation (2013 Data)[2]

This data is consistent with the previous year's report from Massachusetts Department of Public Health. The earlier data showed that RNs and LPNs made up 32% (2010 data), 34% (2008 data), 32% (2007 data) (Laramie MPH, Davis Sc.D, Pun, Laing BS, & DeMaria Jr. MD, 2009, 2010, 2012).

Secondary Stakeholders

The secondary stakeholders are the hospitals, patients, federal bodies (OSHA, CDC), and state regulatory body (Massachusetts Department of Public Health).

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[2] The graph was created using the data from "Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016.

Hospital

The hospital is a secondary stakeholder in the system of needlestick injuries, as it is indirectly affected by caregiver injuries. Even though the hospital is a secondary stakeholder, the Stakeholder Analysis (Figure 2) shows that there are numerous inputs/influences coming into the hospital.

Hospitals needs to not only take care of the patients' health, they also need to address regulations from the federal regulatory body (OSHA), the nation's health protection agency (CDC), the state regulatory body (Massachusetts Department of Public Health), and various health insurance companies.

In order to balance all the influences and properly take care of their employees' and patients' safety, hospitals have an occupational health department. I shadowed at one of the prominent and largest teaching hospitals in Boston. With over 25,000 employees and 100,000 patients treated annually, the hospital has two departments that handle the safety responsibilities. At that hospital, the Occupational Health group is responsible for employees' safety and the *Infection Control* group manages patients' safety and both groups are tightly linked. However, at smaller hospitals, the safety of employees and patients might be handled by one department.

Federal Bodies

There are two federal bodies that are involved with needlestick injuries: OSHA and CDC. OSHA, which stands for Occupational Safety and Health Administration, is a federal regulatory body that reports to Department of Labor, but is not contained within the Department of Labor. OSHA's mission is "to assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance" ("About OSHA Page | Occupational Safety and Health Administration," 2017).

Simply put, they set healthcare practice standards and create laws. In terms of needlestick injuries, this group creates regulations for blood borne pathogens, sharps and needlestick safety (Arbury & Besser, Brett Lamson, 2017b).

The Center for Disease Control and Prevention (CDC), is a federal body that reports to the Department of Health and Human Services. Their mission is to protect US from health, safety, and security threats from foreign and domestic sources ("CDC: Mission, Role and Pledge," 2017). Even though the CDC doesn't create regulations, they provide recommendations on how to manage and reduce needlestick injuries.

State Regulation

In general, the federal regulations for needlestick safety take precedence, unless the state has more strict regulation than federal. As stated in CDC website ("CDC: Bloodborne Infectious Diseases - State-by-State Provisions of State Needle Safety Legislation," 2017), Massachusetts Regulations require:

- Department of Public Health to develop regulations to require hospitals to use sharps with a minimum risk of injury except under certain circumstances
- Department of Public Health to maintain a list of safety devices
- hospitals to maintain written exposure control plans
- appointment of an advisory committee

One additional and unique aspect of the Massachusetts regulation is that it mandates the use of a sharps injury log for continuous improvement of all hospitals ("CDC: Bloodborne Infectious Diseases - State-by-State Provisions of State Needle Safety Legislation," 2017).

Massachusetts Department of Public Health (MDPH) created Massachusetts Sharps Injury Surveillance System in 2001 to collect the sharps injury log data from all hospitals

licensed by MDPH on annual basis. Using research from existing literature, the process of collecting, analyzing and reporting the sharps injury logs in Massachusetts is shown in Figure 4.

MDPH also created a special committee called the *Sharps Injury Prevention Advisory Committee* to help with the development of a Massachusetts sharps injury surveillance system. This committee consists of a variety stakeholders: hospitals, unions and professional organizations (Department of Health and Human Services, 2005). "Most stakeholders were supportive of the new legislation (Massachusetts regulations on sharps mentioned above), which had the potential to improve the safety of healthcare personnel. However, some stakeholders expressed concerns about the state government's lack of funding for this mandate, regulatory burden increase on hospitals, and scope (too wide or too limited) of the proposed legislation" (Department of Health and Human Services, 2005).

MDPH's Occupational Health Surveillance Program releases sharps reports annually from the sharps injury log data. However, one of the limitation of these reports is the logistical fact that the report is published two to three years after the data has been collected. The reason for the delay in publication of the report is unknown, but one could speculate it could be due to large amount of data and/or limited resources. Furthermore, one of the resources reported that Massachusetts Sharps Injury Surveillance System faced several challenges and one of them is limited funding from National Institute of Occupational Safety and Health (Department of Health and Human Services, 2005).

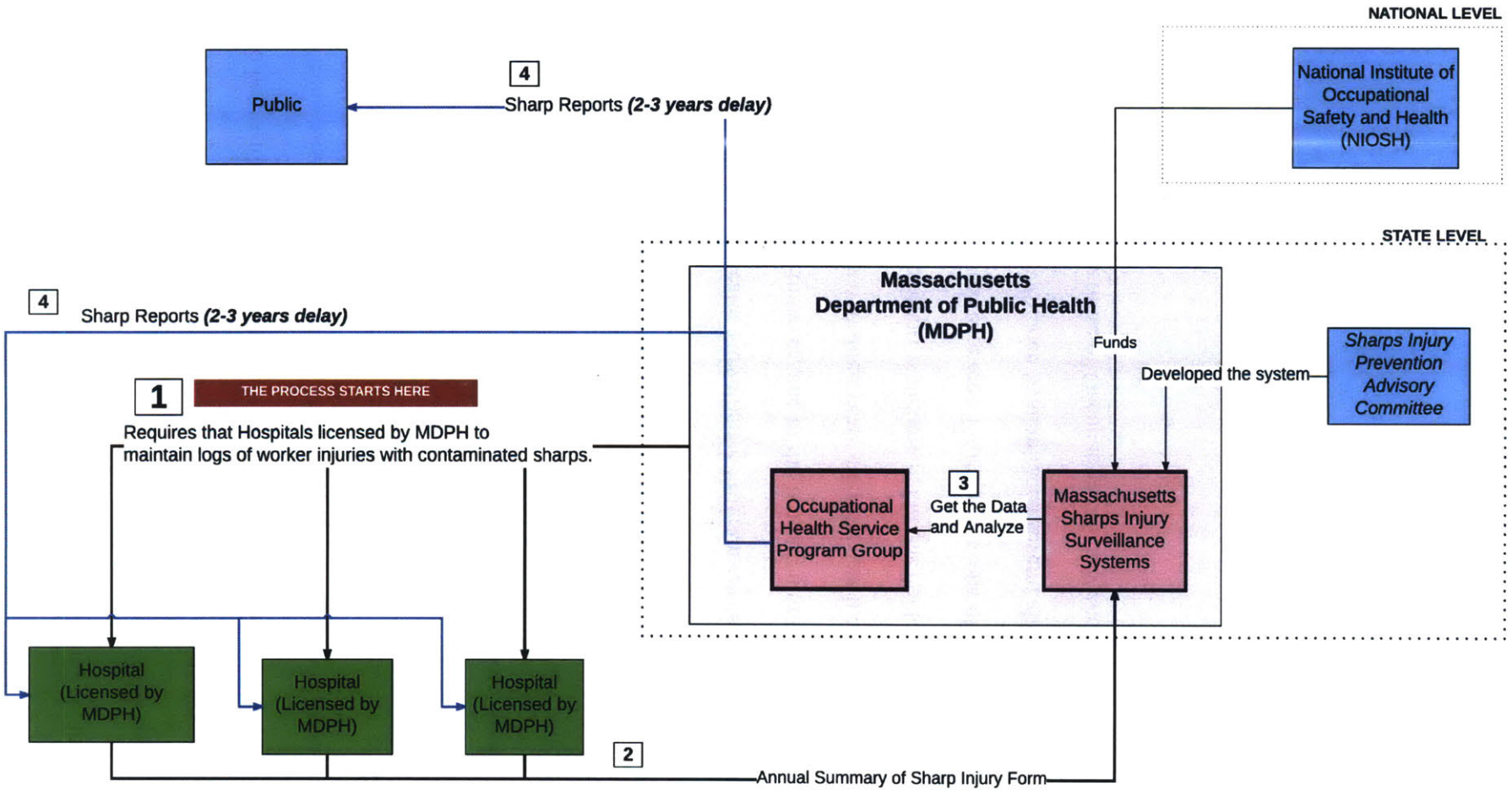

Figure 4: Massachusetts Sharps Injury Report System

Impact on Physical and Psychological Health

Numerous pathogens can be transmitted through needlestick injuries. The three most common pathogens are Hepatitis B (HBV), Hepatitis C (HCV) and Human Immunodeficiency Virus (HIV). The risk of transfer of these pathogens range from 6-30% for HBV for unvaccinated health care workers, 1.8% for HCV and 0.3% for HIV ("CDC: Frequently Asked Questions Bloodborne Pathogens Occupational Exposure," 2013).

Along with fundamental health concerns, there are psychological effects associated with needlestick injuries that are difficult to quantify. A healthcare worker exposure to a needlestick injury results in numerous uncertainties right after the incident. There can be fear, anxiety, and even depression associated with the injury (Hambridge, Nichols, & Endacott, 2016) as the healthcare worker experiences uncertainty about potential pathogen transfer and the implications of potential pathogen transfer on their short-term and long-term health. Furthermore, it can affect his/her quality of life as a feeling of shame or low self-confidence (Hambridge, Nichols, & Endacott, 2016) can come into play as he/she may question his/her job competency as well as the ongoing stress that it could happen again.

Impact on Direct and Indirect Costs

There are two types of costs associated with needlestick and sharps injuries: direct and indirect. Direct costs include labor, laboratory and treatment costs. Indirect costs are harder to quantify as those include the emotional and anxiety associated with needlestick and sharps injuries.

Direct Costs

"The average direct costs, including laboratory costs for tests of both source patients and exposed employees, labor costs associated with testing and counseling, and the costs of post-exposure prophylaxis, are estimated to be $3,042 (ranging from $1,663 to $4,838)" per incident (Laramie MPH et al., 2012). The other costs may include healthcare cost for the healthcare worker who might develop a disease due to the injury (Laramie MPH et al., 2007), as well as the cost of missing work.

In state of Massachusetts employers are required to carry workers' compensation insurance. The workers' compensation insurance pays for all the necessary medical treatment relating to the injury as well as partial compensation for the lost wages after five calendar days ("Employer's Guide to the Massachusetts Workers' Compensation System," 2014). However, there is a cost to the healthcare worker (employee) as if he/she is out of work due to the injury, he/she is only compensated partial wages and not full wages.

Indirect Costs

The indirect costs are harder to quantify but important to mention. The emotional cost to the employees and their families, as well as their morale, are some of the indirect cost of sharps injuries (Laramie MPH et al., 2007).

In the literature, sustaining needlestick injuries brings not only concerns and worry to the healthcare workers, but also affects their quality of life. In a research done primarily on nursing students, Hambridge et al. stated "Reis et al (2004a) described how students exposed to biological hazards ...had feelings of 'insecurity' and 'low self-esteem'. This is echoed by Gupta et al (2008), who found that sharps injuries can have an effect on healthcare workers' quality of life, and can cause great apprehension, angst and fear for themselves, their family and their

colleagues, as well as feelings of shame and low self-confidence" (Gonzalez-Medina and Le, 2011). These psychological effects are not unique to nursing students, but remain true for nurses, doctors, interns and residents.

Causes of NeedleStick Injuries

Some of the common activities that the healthcare worker are performing when the sharps injury occurs are suturing, handling or pass of sharps equipment, during clean up, recapping and disposal. In a German study of 533 healthcare workers, disposal of sharps devices was the highest cause of injury (38%) (Dulon, Lisiak, Wendeler, & Nienhaus, 2016). Disposal of sharps included "on the way to sharps disposal container, working on sharps disposal container, and recapping and waste disposal" (Dulon et al., 2016). The data included hospitals, rehabilitation clinics, dialysis centers, specialty, dental medicine, laboratories, nursing homes for the elderly, care homes and outpatient care services (Dulon et al., 2016).

In comparison, a report by Massachusetts Department of Public Health Occupational Health Surveillance Program in Massachusetts, U.S., from 2004 shows that the biggest occurrence of sharps injury was "collision with sharps or other person" which accounted for 23% of the injuries (Laramie MPH et al., 2007). The disposal and improper disposal accounted for 16% of the sharps injuries from the same report.

Looking at the most recent data (2013) from Massachusetts Department of Public Health, the highest injury causes are suturing (12%), handling/pass equipment (12%), collision with sharps or coworkers (11%) and improper disposal/during disposal was at 10% ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the

Massachusetts Sharps Injury Surveillance System," 2016)[3]. Even though, disposal was one of the highest causes of injury, it was not the highest cause of injury in state of Massachusetts.

Current Prevention Methods

There are numerous prevention methods for needlestick injuries that have been adopted broadly within the health care environment. In U.S., they include "work-practice control, engineering control, personal protective clothing and equipment, employee training, medical surveillance, hepatitis vaccinations, etc." ("Safety and Health Topics | Bloodborne Pathogens and Needlestick Prevention | Occupational Safety and Health Administration," 2017). Even though these prevention methods represent a good start and do, in fact, reduce needlestick injuries, they do not address some of the root causes of needlestick injuries such as high patient load, professional pressure and patient-centric safety culture. These root causes will be further discussed in *Why Injuries Occur in the System* section under *System Analysis and Modeling* chapter.

Work Practice Control are practices that can reduce needlestick injuries such as "no re-capping, placing sharps containers at eye-level and arms reach...emptying sharps containers before they are full and establishing the means for safe handling and disposing of sharps devices before beginning the procedures" (Foley & Leyden, 2017). Engineering Practice Control include having a safety feature on a sharps device to prevent or reduce sharps injuries. These devices are called Safety Engineered Devices.

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[3] The percentage shown per category is compiled percentage from "during use of item", "after use, before disposal", "during or after disposal of item" sections of the report.

The personal protective equipment includes protection for eyes, face, head, and extremities such as wearing gloves, protective clothing, respiratory devices, and protective shields and barriers (Arbury & Besser, Brett Lamson, 2017a). For needlestick injuries, the most critical personal protective equipment are gloves. However, gloves do not fully protect against penetration of needles. The medical surveillance is a broad category, but can include requiring hospitals to record sharps injuries, or keep track of sharps injuries rate over time.

Hospitals are required to provide their employees with hepatitis vaccination series. Most of the people in U.S. receive hepatitis B vaccination as children, however if they have not, hospitals are required to offer hepatitis B vaccinations to their employees (healthcare workers). Hospitals are also required to have post-exposure evaluation and follow-ups for the injured healthcare workers.

Even though the current prevention methods have reduced the incidence of needlestick injuries, they have not reduced needlestick injuries to negligible amount as they do not cover all of the root causes of needlestick injuries such as professional pressure, high patient load/long hours and safety culture mental model. Some of the impracticalities and shortcomings of current prevention methods are discussed in *Impracticality in Current Prevention Methods* under *Social Obstacles with NeedleStick Injuries* section.

Safety Engineered Devices

Safety Engineered Devices (SEDs) are medical devices that have a built-in safety feature to reduce risk of blood-borne pathogen exposure. It is also known as Sharps with Engineered Sharps Injury Protection (SESIP) (Department of Health and Human Services, 2005). In this thesis, SED will be used for consistency.

Types of Safety Engineered Devices

There are various types of safety engineered devices, however, they fall into two main categories: active and passive. SED with active technology requires the user to manually engage the sharps prevention feature (Laramie MPH et al., 2012). The examples of SEDs with active technology are sliding sheath and hinged arm. See Figure 5.

SED with passive technology engages the sharps injury prevention feature automatically: meaning safety feature is engaged without the healthcare workers needing to take any action to engage it (Laramie MPH et al., 2012). An example of passive technology is a retractable syringe where the sharps portion of the syringe automatically retracts after use (See Figure 6). Ideally, all SEDs would have passive technology as there is only a small window of time in which healthcare workers could be exposed to blood borne pathogens when the passive safety technology is not engaged.

However retractable syringes (SEDs with passive technology) primarily come with pre-filled medications. This limits the ability for the healthcare workers to adjust the amount of medication or choose retractable SEDs if the desired medication is not provided in retractable syringes.

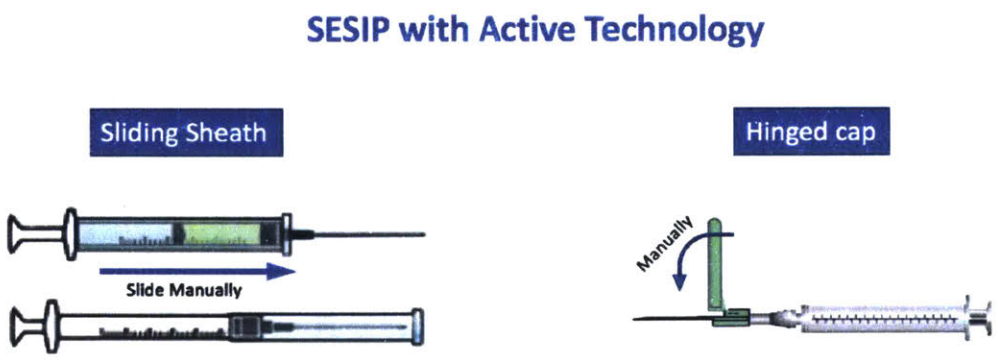

Figure 5: SED with Active Technology[4]

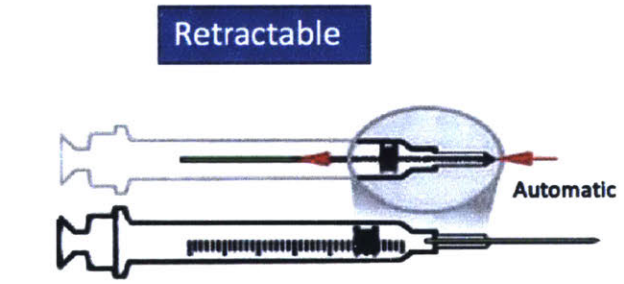

Figure 6: SED with Passive Technology[4]

Another SED that does not fall either in the active or passive categories is a blunt-tip suture needle. Blunt-tip suture needles are "not as sharp as standard (sharp tip) suture needles and are designed to penetrate muscle and fascia and to reduce risk of needle sticks"("Blunt-Tip Surgical Suture Needles Reduce Needlestick Injuries and the Risk of Subsequent Bloodborne Pathogen Transmission to Surgical Personnel," 2012) . Use of blunt-tip suture needles has been

[4] Pictures received from "Annual Summary of Sharps Injury" excel from Massachusetts Department of Public Health http://www.mass.gov/eohhs/gov/departments/dph/

shown to reduce sharps injuries by 87% when only half of the suture needles are replaced by blunt suture needles (Henderson, 2012). However, blunt tip needles are not clinically indicated in a broad range of procedures. Their design limits their use to muscle or connective tissue. The vast majority of suture needles are round-bodied needles that are designed to pierce and spread tissues with minimal cutting.

Figure 7: Blunt Suture Needle[5]

[5] Picture taken from reference "Blunt-Tip Surgical Suture Needles Reduce Needlestick Injuries and the Risk of Subsequent Bloodborne Pathogen Transmission to Surgical Personnel," 2012.

III. Literature Review and Statistics

Comparison of National Data and Massachusetts Data

This thesis revolved around investigating the systematic causes of needlestick injuries specifically in Massachusetts hospitals. In order to better understand the trends and statistics of Massachusetts' sharps injuries, the reports from Occupational Health Surveillance Program of Massachusetts Department of Public Health (MDPH) were reviewed. To give context to Massachusetts data, the sharps that cause the most injuries in Massachusetts were compared with national data.

The national data was derived from the National Surveillance System for Health Care Workers report (NaSH). NaSH is a voluntary surveillance system developed by CDC. Hospital facilities participated from 28 states and District of Columbia and the dates for data collection ranged from 1995-2007 (*CDC: The National Surveillance System for Healthcare Workers (NaSH) Summary Report for Blood and Body Fluid Exposure Data Collected from Participating Healthcare Facilities (June 1995 through December 2007)*, 2007). 81 healthcare facilities participated with NaSH for at least one year between 1995-2007, but any facilities with incomplete data were not included in the report.

In 2000, Massachusetts passed a law, *An Act Relative to Needlestick Injury Prevention* (MGL Chapter 111 §53D), requiring all Massachusetts hospitals licensed by Massachusetts Department of Public Health (MDPH) to collect sharps injury logs and report it to MDPH on an annual basis. (See *State Regulation* section for more details on the data collection process).

The Massachusetts yearly report, published by Massachusetts Department of Public Health Occupational Health Surveillance Program, shows complied data from all Massachusetts

licensed hospitals for one calendar year. The yearly report shows sharps injuries data from the years 2004-2013. However, the publication of each report is delayed two to three years after the data collection, presumably to allow for complete collection and analysis of the information prior to publication. The most recent report (2016) includes data from the 2013 calendar year.

One note of distinction between the national and state (Massachusetts) data is that NaSH data is collected voluntarily and includes mostly large teaching hospitals (81 health care facilities) whereas the Massachusetts data is collected from all licensed hospitals (99 in total) and the hospitals vary significantly in size (*CDC: The National Surveillance System for Healthcare Workers (NaSH) Summary Report for Blood and Body Fluid Exposure Data Collected from Participating Healthcare Facilities (June 1995 through December 2007)*, 2007; Laramie MPH et al., 2007).

The types of healthcare workers also vary in Massachusetts data; the NaSH data (national data) has mostly large teaching hospitals where a percentage of their work force are clinicians in training – residents, interns and nursing students, whereas the Massachusetts data includes a higher percentage of smaller hospitals without teaching affiliations.

Sharps that Cause Most Injuries

From the national data, approximately 55% of the sharps injuries are due to hollow-bore needles (*CDC: The National Surveillance System for Healthcare Workers (NaSH) Summary Report for Blood and Body Fluid Exposure Data Collected from Participating Healthcare Facilities (June 1995 through December 2007)*, 2007). *Hollow-bore needles* are needles used for injections or blood draws from the patients. They "are implicated as the devices most often associated with the transmission of blood borne pathogen infections because the blood remaining

inside the bore of the needle after use. [The hollow-bore needle] contains a larger volume of virus than the relatively small amount of blood remaining on the outside of a solid core needle (e.g., a suture needle)" (Elliott ARNP MSN MPH & Walker RN B.S.N., 1997). *Hollow-bore needle* group includes hypodermic needles, butterfly needles, vacuum tube/needles, IV stylet, and other hollow-bore needles.

The national data is consistent with the data in Massachusetts where 52%-56% of sharps injuries are due to hollow-bore needles ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016; Laramie MPH et al., 2007; Laramie MPH, Davis Sc.D, Pun, Laing BS, & DeMaria Jr. MD, 2008; Laramie MPH et al., 2009, 2010, 2012). See Figure 8.

The consistency in data of national data and state (Massachusetts) data shows that the type of sharps that causes most injuries are of systematic in nature and do not depend on the size or type of hospitals.

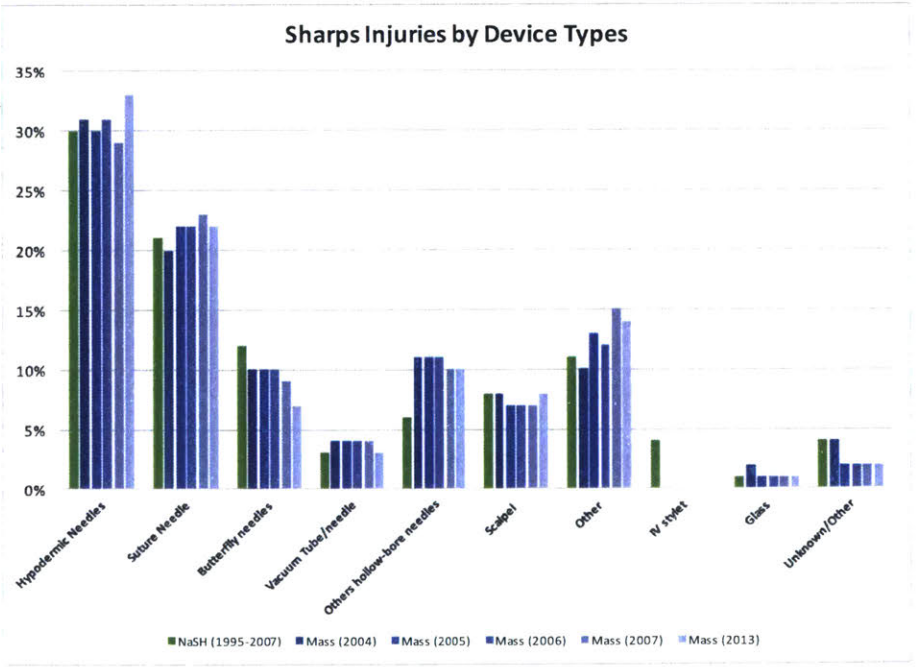

Figure 8: Devices that Cause Sharps Injuries

Primary Stakeholders Affected by Sharps Injuries

Numerous historical data identifies nurses as the primary stakeholders affected by needlestick injuries (CDC, 2015). This is due, in part, to the fact that nurses are the largest segment of the workforce in most hospitals. However, underreporting needs to be accounted for to accurately assume nurses are the most important primary stakeholders.

The national data from NaSH shows healthcare workers' profession not by sharp injuries but by blood and body fluid exposures (*CDC: The National Surveillance System for Healthcare Workers (NaSH) Summary Report for Blood and Body Fluid Exposure Data Collected from Participating Healthcare Facilities (June 1995 through December 2007)*, 2007). Blood and body fluid exposure is defined in the report as exposure from percutaneous (sharps) injuries, mucous membrane, non-intact skin exposure, and bites.

The national data does not show healthcare workers' profession by sharps injuries only, therefore that data is not compared with Massachusetts data, as it would not provide an equivalent comparison.

In Massachusetts, the Massachusetts Department of Public Health (MDPH) publishes reports on sharps injuries sustained among hospital workers on yearly basis. Figure 9 shows the sharps injuries separated by healthcare workers' profession. From the graph, it can be seen that the stakeholders with highest sharps injuries are nurses and physicians, and the data has stayed relatively consistent in the past nine years. Physicians range from 33%-39% and nurses range from 36%-39% of the overall demographics throughout the years.

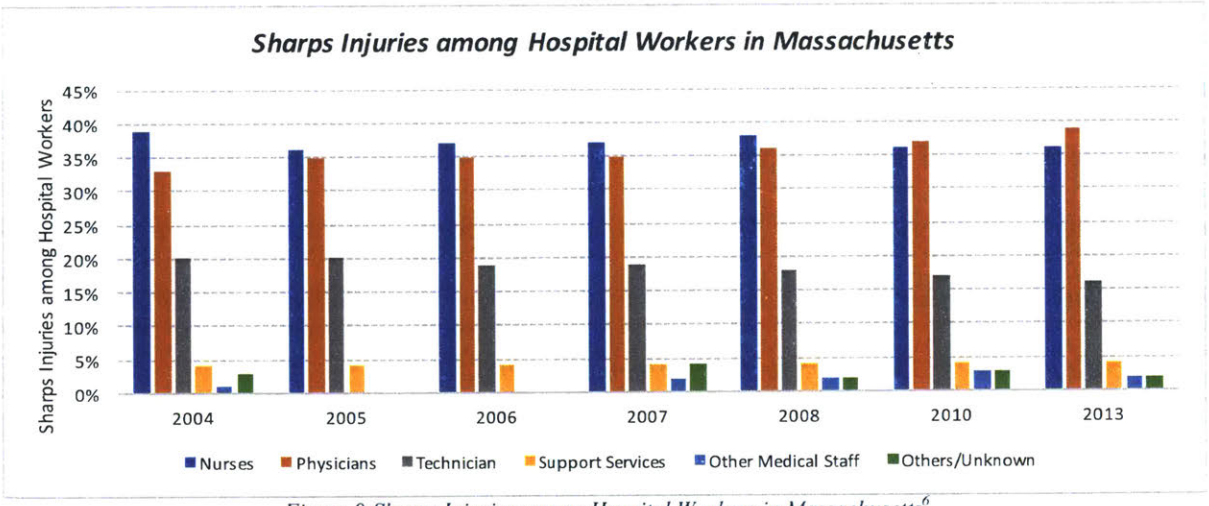

Figure 9:Sharps Injuries among Hospital Workers in Massachusetts[6]

It is important to note that the category 'nurses' includes nursing students, RN/LN and nurse assistants. From 2013 data, RN/LN accounted for 31% out of the 36% 'nurses' category and within the 'physicians' category, 14% out of the 39% were sustained by interns/residents and 11% out of 39% were attending physicians. Therefore, if 2013 data was to be ranked, RN/LN accounted for 31% of overall sharp injuries, then interns/residents at 14% and attending physicians at 11%.

One key factor to consider while comparing statistics of healthcare workers sustaining sharps injury is underreporting. Underreporting occurs when the healthcare worker sustains a sharps injury but does not report it due to various reasons: busy schedule, fear of repercussion on their jobs, perception of low infection risk, etc. (See *Underreporting* section for thorough explanation).

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[6] Graph created using data from these reports ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016; Laramie MPH et al., 2007, 2008, 2009, 2010).

NaSH report shows that "[even with large number of reported percutaneous/sharps injuries], results from [healthcare personnel] questionnaires during this period [1995-2007] suggest these [reported injuries] represent less than half the total number of injuries that actually occurred during this period"(*CDC: The National Surveillance System for Healthcare Workers (NaSH) Summary Report for Blood and Body Fluid Exposure Data Collected from Participating Healthcare Facilities (June 1995 through December 2007)*, 2007).

Furthermore, another report suggest that "underreporting of sharps injuries by employees (healthcare workers) is well documented in the literature with estimates ranging from 22% to 99%, and has been found to vary by occupation and by hospital" (Laramie MPH et al., 2012).

Therefore, to get an accurate representation of demographic of healthcare workers by profession, underreporting needs to be reduced. Nurses should not be the only focus group on sharps injury reduction, but it should also include residents/interns, and attending physicians.

Departments Most Affected by Sharps Injuries

The national data from NaSH did not show data of exclusively sharp injuries separated by departments, therefore the national data was not compared with Massachusetts data.

Using the Massachusetts data from MDPH reports it can be seen that less than half of the all sharps injuries occur in operating and procedure rooms. (See Figure 10). Operating and procedure rooms accounts for 43-45% of incidents and in-patient care accounts for 21%-22% for sharps injuries (by department) in the 2004-2013 data.

Due to underreporting, the assumption should not be made that operating room and procedure rooms are the main source of sharps injuries. They should be one of many departments that sharps injury reduction should be implemented.

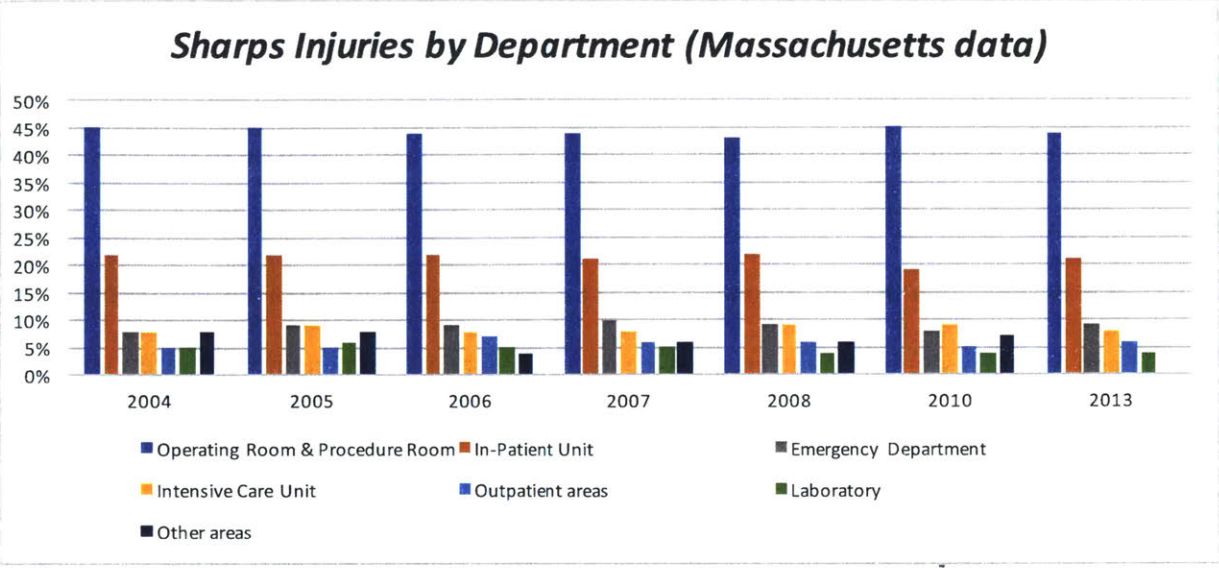

Figure 10: Comparison of Departments with Reported Sharps Injuries[7]

Safety Engineered Devices are Not Failsafe

Even though safety engineered devices (SEDs) are designed to reduce the risk of disease exposure, they are not failsafe. Despite the safety features, data from 2013 from the Massachusetts Sharps Injury Surveillance System shows that 46% of the sharps injuries still occurred with safety engineered devices ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016). The data does not allow the reader to understand if the rate of injury is different between devices, only that the overall number of injuries remains high even with implementation of SED technology.

However, it is important to note that even though the data suggest more injuries are caused by safety engineered devices versus sharps with no safety feature for hollow-bore needles

[7] The graph was created using data from these reports ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016; Laramie MPH et al., 2007, 2008, 2009, 2010).

(because there are no inventory data shown) we cannot conclude safety engineered device cause more injuries. It could simply be that there is more safety engineered devices present in hospitals than sharps devices with no safety features. Comparative percentages based on usage rates would be needed.

It is worth noting that the graph (Figure 11) is pulled from the Massachusetts report from MDPH and represents safety engineered device as SESIP (sharps with engineered safety injury prevention).

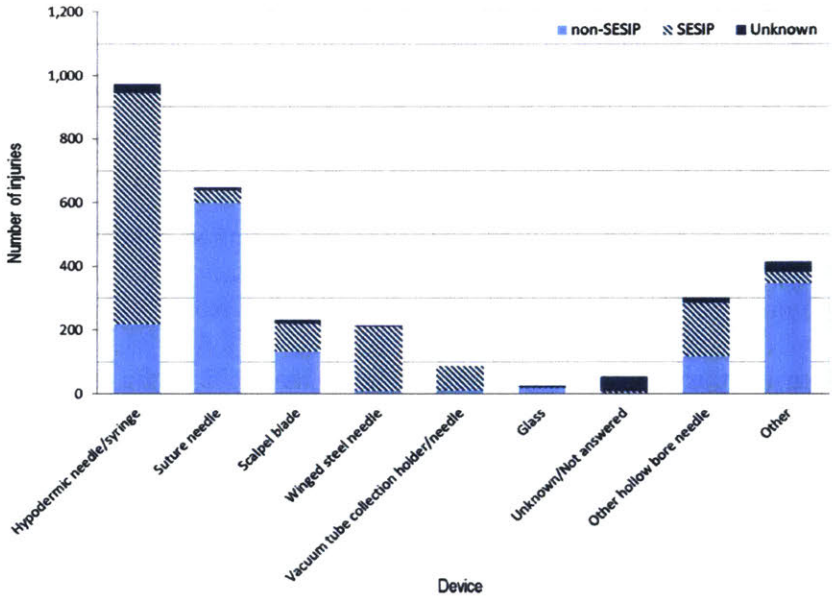

Figure 11: Number of Injuries distinguished by Device Type, Massachusetts 2013[8]

In the state of Massachusetts hospitals are required by the Department of Public Health to use "only such devices which minimize the risk of injury to health care workers" unless there are circumstances that the hospital can prove that SEDs would get in way of medical procedure or

[8] This figure is taken from ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016).

employee/patient safety ("CDC: Bloodborne Infectious Diseases - State-by-State Provisions of State Needle Safety Legislation," 2017). Therefore, an assumption could be made that majority of the hollow-bore needles would be safety engineered devices. As for suturing and scalpels, the only safety engineered devices available for suturing are blunt-tip suture needles which are only applicable in certain types of procedures.

The latest Massachusetts data of 2013 does not identify which SED caused the most injuries. However, from the 2010 data, of all the safety engineered devices, the sliding sheath caused 42%, hinged arm caused 29% and retractable design caused 24% of overall sharps injuries (Laramie MPH et al., 2012). SEDs that have to be manually engaged (SED with active technology) appear to be implicated in the majority of injuries.

The number of different type of purchased SEDs is not given, and therefore we cannot assume SED active technology causes the most injuries. However, for the purposes of this thesis, the assumption is made is that an SED with active technology would cause more injuries because it requires manual intervention by the health care worker and as a result, there is longer time where the contaminated needle is being manipulated versus the passive SED where the safety feature is engaged right after the needle is used.

In a system analysis, one needs to realize that SED is an engineering solution and in order for it to be fully effective, the social aspect needs to be addressed such as the additional manual step and training on how to properly use SED. A research study that surveyed 533 healthcare workers that had received sharps injuries showed that 110 of these injuries were caused by safety-engineered devices (Dulon et al., 2016). Out of those 110 SED sharps injuries, 70 occurred with healthcare workers that had received training (64%) and in 39 cases, the training had occurred less than a year before (Dulon et al., 2016). Furthermore, even though some of the

healthcare workers reported the injury was caused by product defect, the "vast majority reported that the accident had been caused by their lack of experience with SEDs" (Dulon et al., 2016). This data shows that not only do the healthcare workers need to receive training, but there needs to be careful assessment of the depth and approach to training, as well as the frequency with which it is conducted.

Social Obstacles with NeedleStick Injuries

The current NSI prevention methods are "work-practice control, engineering control, personal protective clothing and equipment, employee training, medical surveillance, hepatitis vaccinations, etc." ("Safety and Health Topics | Bloodborne Pathogens and Needlestick Prevention | Occupational Safety and Health Administration," 2017). Authors Mary Foley and Annemarie T. Leyden stated in *Independent Study Module on Needlestick Safety and Prevention* that "over 80% of needlestick injuries can be prevented with the use of safer needle devices (CDC, 1997), which, in conjunction with worker education and work practice controls, can reduce injuries by over 90% (Jagger, 1996)."

However, even though safety devices have demonstrated reduction in needlestick injuries; needlestick injuries have not been eliminated. In Massachusetts (MDPH report), the number of sharps injuries reduced over time but has plateaued at approximately 15 sharps injuries per 100 licensed beds (See Figure 12).

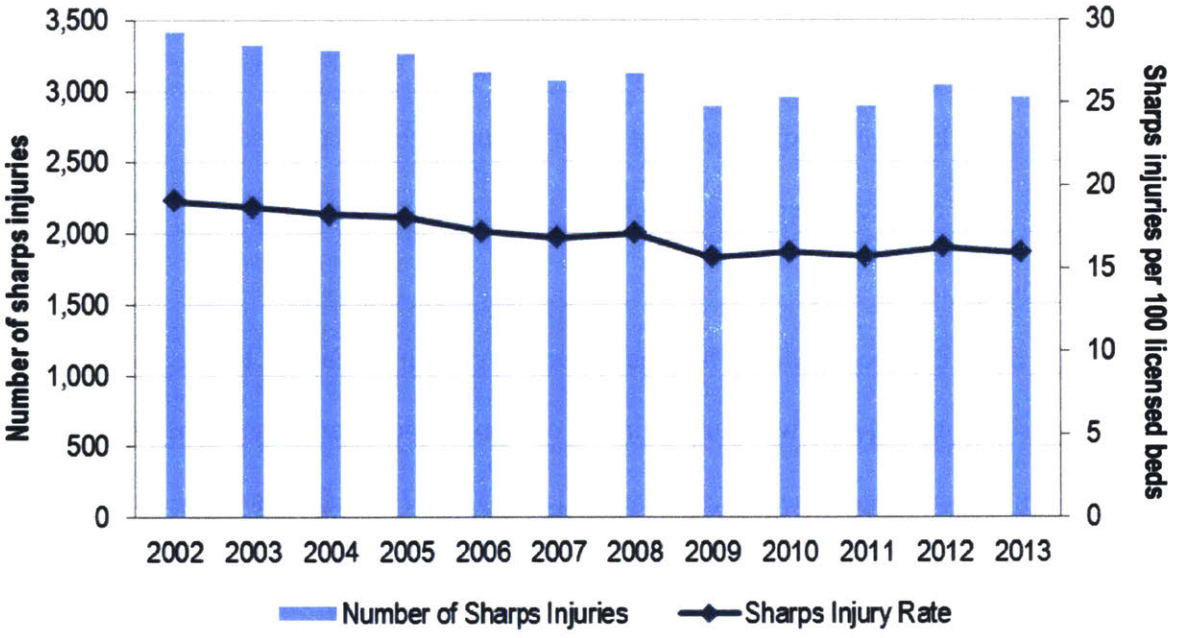

Figure 12: Number of sharps injuries in Massachusetts[9]

There are social factors that make it hard for needlestick prevention methods to reduce needlestick injuries further. One of those factor is underreporting. Even though underreporting does not cause needlestick injuries, they misrepresent the actual number of injuries by underestimating them. Therefore, in order to gain an accurate picture of needlestick injuries per year, underreporting needs to be addressed.

Another factor that needs to be addressed is inadequate training. The current prevention methods include training, but the section below shows that training alone cannot be the solution; training needs to be effective and frequently given.

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[9] Graph taken from the report ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016)

The final factor that is connected to needlestick injuries is the safety culture surrounding use of sharps devices. Hospitals put high emphasis on patients' safety and patients' health. However, the same level of importance is not given to employees' health and that is discussed below to show how it affects needlestick injuries.

Underreporting

Underreporting occurs when a healthcare worker sustains an injury, but does not report it. NaSH report shows that "[even with large number of reported percutaneous/sharps injuries], results from [healthcare personnel] questionnaires [from 1995-2007] suggest these [reported injuries] represent less than half the total number of injuries that actually occurred during this period"(*CDC: The National Surveillance System for Healthcare Workers (NaSH) Summary Report for Blood and Body Fluid Exposure Data Collected from Participating Healthcare Facilities (June 1995 through December 2007)*, 2007). Another report shows that "underreporting of sharps injuries by employees (healthcare workers) is well documented in the literature with estimates ranging from 22% to 99%, and has been found to vary by occupation and by hospital" (Laramie MPH et al., 2012).

For sharps injuries in general, there are multiple reasons why healthcare workers might not report the incident. One of the reasons is healthcare workers' busy schedule and their perception that reporting is time consuming. In *A Call to Arms to Prevent Sharps Injuries in Our ORs* article, a chief of surgery reiterates this point. "[Healthcare workers] are all faced with the tremendous inconvenience and time burden of reporting, which in the middle of a busy day is simply unworkable if [they want] to continue performing and taking care of the patients who are scheduled to have surgery in a busy OR" (Guglielmi et al., 2010).

Another reason that healthcare workers do not report is they have a misperception that the infection risk is low (Tandberg, Stewart, & Doezema, 1991). Although the incidence of virus transmission is real, they assume that the chance the contaminated blood contains a virus is minimal. Furthermore, some healthcare workers might be concerned that reporting would reflect poorly on their job performance. They believe that reporting could jeopardized their career as it can be viewed as technical incompetence (Henderson, 2012).

Doctors are even less likely to report than nurses or other healthcare workers. In a report by Tandberg, a questionnaire was given to more than 150 emergency physicians, emergency nurses and EMTs. Physicians reported only one eighth of their exposures compared with EMTs and nurses, who each reported approximately two thirds of their exposures (Tandberg et al., 1991). "One of the explanation is that many physicians are self-employed and do not feel that there is much personal gain in reporting, whereas nurses and EMTs often work for large corporations and are perhaps more accustomed to 'incident reporting' for self-protection"(Tandberg et al., 1991).

Furthermore, the social perception of doctors could also come into play. From the interview section, the professional pressure is a factor when reporting is concerned. "The root cause of why [needlestick injury] happens and why there is a barrier to report it is pressure. *Professional Pressure*...there is a myth that doctors are supposed to be perfect and do everything" (Dr. M, personal communication, April 13th 2017). This perception of being perfect and never making mistake is challenged when an injury occurs and this could lead to underreporting.

Underreporting is one of the important social issues that needs to be tackled if needlestick injuries are to be eliminated. To systematically focus on reduction in needlestick injuries,

training and education for the healthcare workers on needlestick injuries risks is important as well as encouraging healthcare workers to report sharps and needlestick injuries. Therefore, any needlestick injury reduction plan needs strategies to encourage healthcare workers to report as well as reduce the actual injuries.

Inadequate Training

One of the social factors that limits the reduction of needlestick injuries is inadequate training of health care workers. The current training typically consists of two components. First, there is training on background and risks of needlestick injuries. Second, there is training on usage of safety engineered devices (SED). Training needs to be repeated on a regular basis to provide refresher on techniques and reminder of importance of needlestick injuries. Even though many devices have safety features integrated to their design, the rate of needlestick injuries is decreased but not completely eliminated. Training is still an essential component that works in parallel with the needle safety design.

An example of effect of inadequate training is described in a journal article, Causes of needlestick injuries in three healthcare settings: analysis of accident notifications registered six months after the implementation of EU Directive 2010/32/EU in Germany, Journal of Hospital Infection (2016*)*. In this research, a survey was given to healthcare workers in hospitals, doctors' offices, in-patient and outpatient care in Germany.

533 healthcare workers participated in the survey and the data showed that 20% of needlestick injuries occurred while using safety engineered devices. Out of the 110 SED injuries, in 70 of those cases, their workplace had offered training on SED and 39 out of those 70 cases had taken training 12 months preceding the accident. All of healthcare workers who sustained injuries using SED stated that "their handling experience was inadequate"(Dulon et al., 2016),

showing that even though training was provided, the workers perceived that the training was not adequate to safely use the devices. While this study was done in Germany, interviews with clinicians indicate that similar issues are prevalent here in the United States.

This data shows the importance of proper and effective training. In order to reduce and eliminate NSIs, providing SEDs to healthcare workers cannot be the only solution. There needs to be proper training on correct usage of SED and the training needs to be repeated to refresh healthcare workers' expertise on a regular basis.

Safety Culture

The culture of safety is of high importance in hospitals. The primary focus of that culture is geared towards patients. In an article by U.S. News & World Report, United States hospitals are ranked. The criteria focus on four main elements while ranking "reputation, patient survival, patient safety and care-related factors such as the amount of nurse staffing and the breadth of patient services" (Comarow, 2016). Three out of the four factors are patient-centric. This hospital ranking is public and widely read. As a result of the influence of this study, hospitals put much of their focus on ensuring patients' care and safety.

Unfortunately, the same level of focus and dedication towards patients is not always provided to the healthcare workers that care for them. In a journal article published in the Association of periOperative Registered Nurses Journal (AORN), the perspectives of four different healthcare workers are provided: a nurse, a surgeon, a surgical technologist and infection prevention personnel. In the article, a nurse mentions that "'a culture of safety' has been used by the health care community to let patients know that they are doing everything [they] can to care for [the patient] in a manner that will result in the most positive outcomes

possible; however, that culture has not applied equally to the safety of team members caring for the patient" (Guglielmi et al., 2010).

This culture of safety should not be limited to patients only, but should also apply to the healthcare workers. To transfer the safety culture of patients to patients *and* healthcare workers is no easy task as it requires changing mental models of healthcare workers. However, by emphasizing the importance of safety culture for healthcare workers, it will encourage healthcare workers to take adequate precautions. The commitment of safety will also encourage the healthcare workers to report any unsafe practices and injuries.

Impracticality in Current Prevention Methods

Some of the other sharps prevention methods include double-gloving, usage of blunt suture needles and neutral zone for perioperative care (Guglielmi et al., 2010). Blunt-tip suture needles are needles that are "not as sharp as standard (sharp-tip) suture needle [and] are designed to penetrate muscle and fascia and reduce risk of needlestick ("Blunt-Tip Surgical Suture Needles Reduce Needlestick Injuries and the Risk of Subsequent Bloodborne Pathogen Transmission to Surgical Personnel," 2012). The neutral zone is a technique where no direct handing of sharps from one healthcare worker to another occurs. The neutral zone can be a basin, a towel, or a magnetic mat (Guglielmi et al., 2010). However, not all the methods are being practiced or practical.

In one of the articles published on AORN mentions the reality of the situation. A surgical technologist from CA mentions that "double gloving is not used by many surgical team members because it can be uncomfortable and decrease tactile sensation" (Guglielmi et al., 2010). In the same article, a nurse from NY mentions that she has seen changes with regards to safety and double gloving by scrubbed personnel has become more normal.

In some places, blunt suture needles are used and one multicenter study suggested that when only half of the suture needles were blunted, injuries were reduced by 87% from curved suture needles (Henderson, 2012).

However, there is some pushback from healthcare workers. One area of resistance comes from scalpel safety design. A surgical technologist mentions "[some surgeons have] stated the scalpels with retractable covers do not work as well as regular scalpels" (Guglielmi et al., 2010). A nurse from NY also comments "the most difficult change to manage is the implementation of safety scalpels. Industries have spent time, money, and effort to develop a scalpel that surgeons will find similar to the blades they are accustomed to using, but this continues to be the most problematic issue" (Guglielmi et al., 2010).

Even with neutral zone method, some surgeons care about operation room safety. They "prohibit hand-to-hand passage of sharps instruments; and, in instances in which such instruments must be directly passed, the hand-off is orally announced prior to instrument passage" (Henderson, 2012). However, from another surgical team, a surgical technologist mentions that when the OR team is rushed during procedures there is not always time for the implementation of a neutral zone to be effective (Guglielmi et al., 2010).

One of the key takeaway is that even though current prevention methods are in place, not all hospitals/surgical teams will implement them. It could be due to healthcare workers' resistance to change, but in many cases, it is due to busy schedules or impracticality of the prevention methods. Therefore, the healthcare workers' workforce timing pressures are an important consideration when proposing a systematic solution.

Literature Review Summary

The literature review shows that there are multiple layers to needlestick injuries and different social obstacles that prevent it from being eliminated. Therefore, moving forward, it is important to look at the holistic picture surrounding needlestick injuries to fully grasp the problem and propose solutions that cover all aspects and root causes of needlestick injury system.

IV. Interviews

"The root cause of why [needlestick injury] happens and why there is a barrier to report it is, pressure. *Professional Pressure.*"

"There is a myth that doctors are supposed to be perfect and do everything. Of course, it is never true... but especially when you are resident, you are part of *that culture* and you are trying to be this *perfect person.*"

- Doctor (Dr. M.)

"Underreporting is about admitting you made a mistake...I think lot of it really is more just them not wanting to admit they made a mistake and do a risk factor for themselves"

"A resident feels if he injuries himself, he has to step away from OR to take care of that. [He thinks] he is [not going to be reviewed] as favorably by the attending physicians as the other residents...These are people who are high performers, they strive to be perfectionist."

"I think it is [also] time, to me, the resident who doesn't want to miss anything in his training, to have to break scrub in the OR, come to [Occupational Health], get blood drawn and get prophylaxis."

-OSHA Director (Mr. A.) of a Hospital's Occupational Health Department

In order to gain a deeper understanding of needlestick injuries a group of primary stakeholders, including a doctor, nurse, nurse practitioner and OSHA Director of Occupational Health were interviewed. In order to protect the identity of the interviewees, their names are not disclosed in this thesis. The doctor is referred to as Dr. M. and the OSHA Director is referred to as Mr. A.

It is important to note that the nurse practitioner, OSHA Director, and the nurse are from the same hospital. The hospital is one of the largest reputable hospitals (Hospital A) in Boston, Massachusetts, and is the same hospital where I shadowed a clinician. The doctor that was interviewed currently works at a different hospital (Hospital B), but is affiliated with Hospital A. He also completed his residency in Hospital A.

The interviews were informal. Three main themes emerged during interviews: root causes of underreporting, patient centric safety culture and training.

Root Causes of Underreporting

Underreporting is a common problem with needlestick injuries. Some of the causes of underreporting mentioned in literature were inconvenience, low infection risk perception and job competency (Guglielmi et al., 2010; Henderson, 2012; Tandberg et al., 1991). However, the real root causes of underreporting lie in the professional pressure especially on doctors and their nature of self-assessment.

Doctor's Perspective

The doctor that was interviewed is a primary care physician and has been practicing medicine for 16 years. He had experienced needlestick injury as a resident in 2000/2001.

He described the root cause of needlestick injuries as professional pressure. "The root cause of why [needlestick injury] happens and why there is a barrier to report it is, pressure. *Professional Pressure*...to be efficient, see as many patients as possible, and do that while being viewed as competent."

He described his experience with needlestick injury as an incident during his residency years in 2000/2001. He was working a 10-12 hours evening shift in the emergency room. The injury occurred when he was drawing blood from HepC positive patient. The nurses were having difficulty drawing blood and the doctor (then resident) was brought in. He remembered wearing gloves and stuck himself on his left finger while using the needle with his right hand.

When asked how he felt immediately afterwards, he mentioned he wanted to ignore it happened and kept working. There was no clear protocol at that time to report needlestick injuries. However, once he mentioned it to the attending physician, he/she told him to go report it. He received a needlestick injury beeper, and one of the Infection Disease clinician called him. He was prescribed HIV prophylaxis medication, which he picked up next day. Over the next few weeks, he had series of HIV and HepC tests and was found not to be infected.

A part of the story I found interesting was his interaction with the patient after the injury. He described this interaction as unusual and that "[the patient] was very apologetic. It is often not the case. Even thought he was little out of it, and little intoxicated, he kind of knew that it happened. He kind of saw me freaking out or talking to [someone]. That is something that I could have handled little bit better. I clearly revealed what had happened."

I found that quote interesting as he felt letting the patient know he had been injured was something wrong. His response indicated that he felt like doctors are not allowed to be vulnerable in front of the patient.

"[There is a] cultural piece…there is a myth that doctors are supposed to be perfect and do everything perfectly and do everything very fast. Of course, it is never true. You get used to the fact that it is never true, but especially, when you are resident, you are part of that culture and you are trying to be this perfect person. That affects all physicians at any point in their life but affects residents more."

OSHA Director's Perspective

The OSHA Director that was interviewed worked in Occupational Health Services department in Hospital A in Boston, MA. He has been working in Occupational Health for 15 years and has been a director for past 12 years.

When asked about the root causes of underreporting, he suggested few causes. The underlying cause he mentioned was cultural perception of doctors and their tendency to be perfectionist.

"Underreporting is about admitting you made a mistake. I think in healthcare, it is one of the fields… where if you make a mistake, there [are] consequences. For this, it is their own health, so they think the consequences are less, so maybe they don't report… These are people [doctors and residents], who are high performers, they strive to be perfectionist."

He also mentioned other root causes such as time and unfavorable review. "I think it is time, to me, the resident who doesn't want to miss anything in his training, to have to break scrub in the OR, come to [Occupational Health], get blood done and get prophylaxis." "We have people who injure themselves, they don't want their boss to know. A resident feels if he injuries himself, he has to step away from OR to take care of that, he is [not going to be] reviewed as favorably by the attending physicians as the other residents."

Safety Culture

The healthcare field puts high importance on safety. However, in literature, they have shown the culture of safety focuses primarily on patients. The focus is so much on patients that doctors/nurses sometimes jeopardize their own health.

OSHA Director's Perspective

"I am in the military, every time I go to the firing range, I am thinking I have a loaded weapon, I need to be extra safe and I think [healthcare workers] don't think [when they] come to work there is a chance [they can] get stuck with a [contaminated] needle. They are just thinking, do they have the right dose [of medication], do [they] have the right patient, they are not thinking, [they] need to protect [themselves] and … [one of] the last thing [healthcare workers] think about is about their own safety in healthcare."

Doctor's Perspective

The doctor was asked if the safety culture was taught differently to new resident from patient-centric to patient *and* healthcare workers focused, if it would make a difference? His answer was "yes."

"I think it would help… There is implicit and explicit learning…Implicit learning is the message you get from people above you, people you are learning from, about how to behave or what is the right thing or how you need to be." Explicit learning is what you are taught, something you learn consciously such as trainings. "There has been a big push in residency program [since my residency] …to limit workhours, improve self-care, reduce level of fatigue."

"There is a huge effect to change the [implicit] curriculum as well as the explicit curriculum…. Before, both of those curricula was more about old myth of the 'perfect' doctor,

[who] does what needs to [be done] for the patient and never gets tired. In the new era, [implicit curriculum and explicit curriculum] has more to do with self-care. Both have moved together, [but] explicit curriculum leads the implicit. There is a lag time." The lag time between implicit and explicit is because healthcare workers who live through the "old way" believe in the old philosophy and do not necessarily want to change it.

Training

There were multiple types of training that were discussed during the interviews: training on use of safety engineered devices, training on safety protocols and practices, and general training on basic skills.

Some of the takeaways from the interviews were the training for doctors on basic skills such as drawing blood has improved throughout the years. The education on sharps devices and safety protocols are being implemented at hospitals. However, there are limitations on training in a large hospital due the large size of employees.

Doctor's Perspective

One of the things the doctor mentioned was he wished he had more training on basic skills such as blood drawing and procedures [before or during his residency]. He sustained needlestick injury during his residency in 2000/2001, while being called in to draw blood from a patient. He was called in as the nurse was having a difficult time with the blood draw.

"There is a cultural procedure, if nurses can't get it [draw blood], if IV nurse can't get it.... then it bumps to the doctor. Yet, the doctor is the least well-trained.... There is a weird disjunction, where the doctors are the backstop for everything, but we are not always trained [adequately] for all this stuff that we are backstop for."

"Some things that has gotten better since then [2000/2001] are some of the safety [engineered] devices [and simulation training]." There is a big simulation training at the hospital he initially did his residency (Hospital A), where the residents work on mannequins with sensors and realistic skin. "[In 2000/2001, there] was not as real deep culture of techniques and getting it right that they are doing it right now with simulation... which applies to everything, IV, center lines, running codes, emergency. They do that much better now."

Nurse Practitioner's Perspective

The nurse practitioner that was interviewed is a veteran nurse practitioner who works at Hospital A. She currently works in the Occupational Health department along with the OSHA Director.

When asked what can be done to reduce needlestick injuries, she mentioned education, repetitive training and techniques. "I do training for new residents and fellows, I go over 'never recap, never recap, never recap.' I say it three times." She trains them on popular safety engineered devices as well as proper techniques to engage the safety feature. "One of my goals this year is to make myself present on a weekly basis to different [in-patient] nursing departments. [I would like to] reinforce and educate the proper use [and] proper technique for any safety devices they do have. Lot [of it] might be repetition for the nurses [but] I feel like a lot of the young nurses come in and sometimes they are afraid to ask questions."

She also discussed the usefulness of video training. "[One of the Occupational Health clinician] did an [online] video. We were having problems with a particular [safety engineered device]. [When enabled], you hear it and you sense it." The video was useful as the nurses could review it whenever it was convenient for them and get a quick refresher.

OSHA Director's Perspective

When interviewing the OSHA Director of Occupational Health, we discussed training as a method to educate on safety engineered devices. However, he described the limitation of training in large hospital.

"When there is new [safety engineered] device that comes out, we do our best. But again, there are 25,000 people here [some are part-time or on medical leave]. Even if we do training right now [for] everyone on everything, three months from now, someone is out because they had a baby. [Therefore, someone will miss the training and it is hard to catch]. There is that on-going training that is tough."

The Occupational Health department does hands-on training for all medical trainees, residents and fellows in that hospital. But there is not a process to catch nursing students. Furthermore, there are many different types of safety engineered devices and therefore it is not realistic to train everyone on everything. That is one of the limitations of training in a large hospital, someone will miss out on training and it is harder to capture who missed it.

V. System Analysis and Modeling

The System

A simple system diagram can be drawn for needlestick injury (See Figure 13). The system consists of an operator or injured health care worker and a sharps device. Outside of the system boundary, the external influences that can cause needlestick injuries are identified: co-workers, the patient or the disposal container.

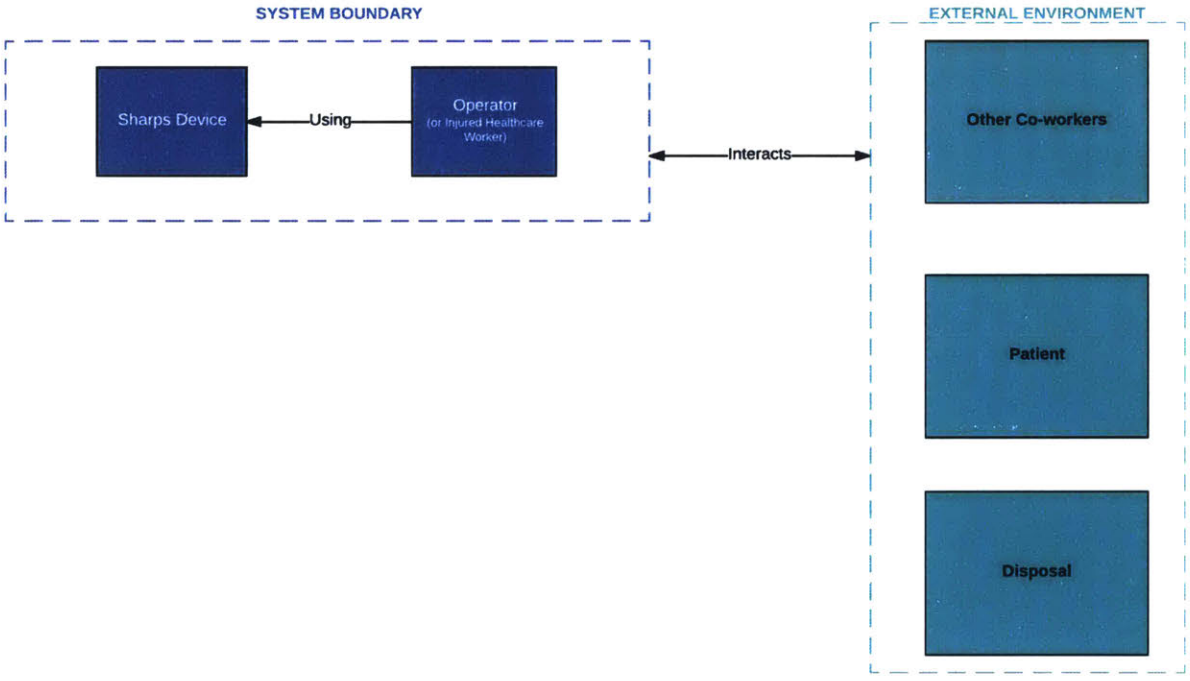

Figure 13: Needlestick Injury System Diagram

Identifying Cause and Effect: Fishbone Diagram

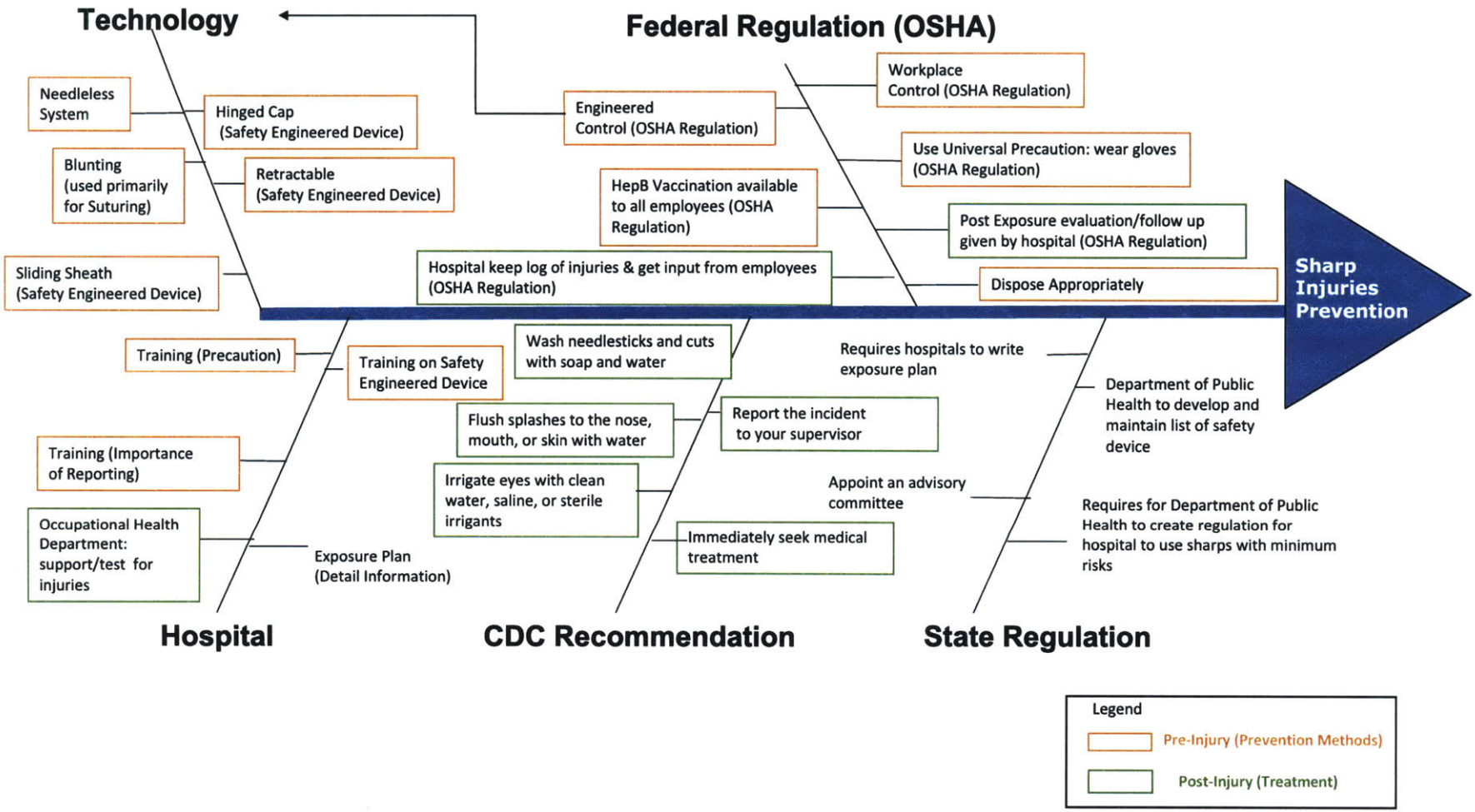

Figure 14: Fishbone Diagram used to describe different form of prevention methods

The fishbone diagram is used to show different sectors that provide sharps injury prevention methods (See Figure 14). The different sectors are the federal and state regulatory bodies, hospital, CDC, and technology.

Sharps Regulation by OSHA

The first prevention method is from the federal regulatory body; OSHA. OSHA regulations are written for blood borne pathogens, sharps/needlestick injuries and safety devices (Arbury & Besser, Brett Lamson, 2017b).

To minimize the blood borne pathogens, OSHA recommends: engineering control, work practice control, use of universal precautions, proper handling of disposal, employers (hospitals/clinics) provide option of HepB vaccination, post-exposure evaluation and follow-up for all employees, and (the hospitals/clinics) keep log of injuries and get input from employees on workplace and engineering control improvement (Arbury & Besser, Brett Lamson, 2017b).

OSHA's work practice control includes training such as prohibiting recapping of needles, under universal precautions such as wearing gloves and disposing of any needles.

OSHA defines engineering control as "measures (e.g. sharps disposal container, self-sheathing needles, safer medical devices such as sharps injury protections and needleless systems) that isolate or remove the blood borne pathogens hazard from the workplace" (Arbury & Besser, Brett Lamson, 2017b). Stemming from OSHA's engineering control regulation is technology designed to minimize sharps injury.

Technology

The technology is the safety engineered devices (SEDs) that reduce or prevent needlestick injuries. The types of safety engineered devices that are listed under Technology are

hinged cap design, blunting of suture needles, retractable needles, sliding sheath design and needleless system.

State-Level (Massachusetts) Regulation

All states follow the federal regulations unless the state has stricter laws than federal. However, Massachusetts has additional stipulations. The Massachusetts Department of Public Health (MDPH) requires institutions to create regulations for hospitals to use sharps with minimum risks, to develop and maintain safety device list, appoint an advisory committee for Sharps Prevention, and write exposure plans ("CDC: Bloodborne Infectious Diseases - State-by-State Provisions of State Needle Safety Legislation," 2017).

Stemming from the regulations at a federal and state government level, the hospitals are required to have a detailed exposure plan. In additional, hospitals have training on precautions, sharps injury reporting and use of safety engineered devices for the healthcare workers as sharps prevention and treatment plan.

CDC Recommendation

CDC recommendations are not regulations but recommendations for the healthcare workers in the event of an injury such as washing the cut with soap and water, flushing the injury, reporting the incident and seeking medical treatment ("CDC: Bloodborne Infectious Diseases - Emergency Needlestick Information - NIOSH Workplace Safety and Health Topic," 2017).

How the System Operates on Normal Conditions

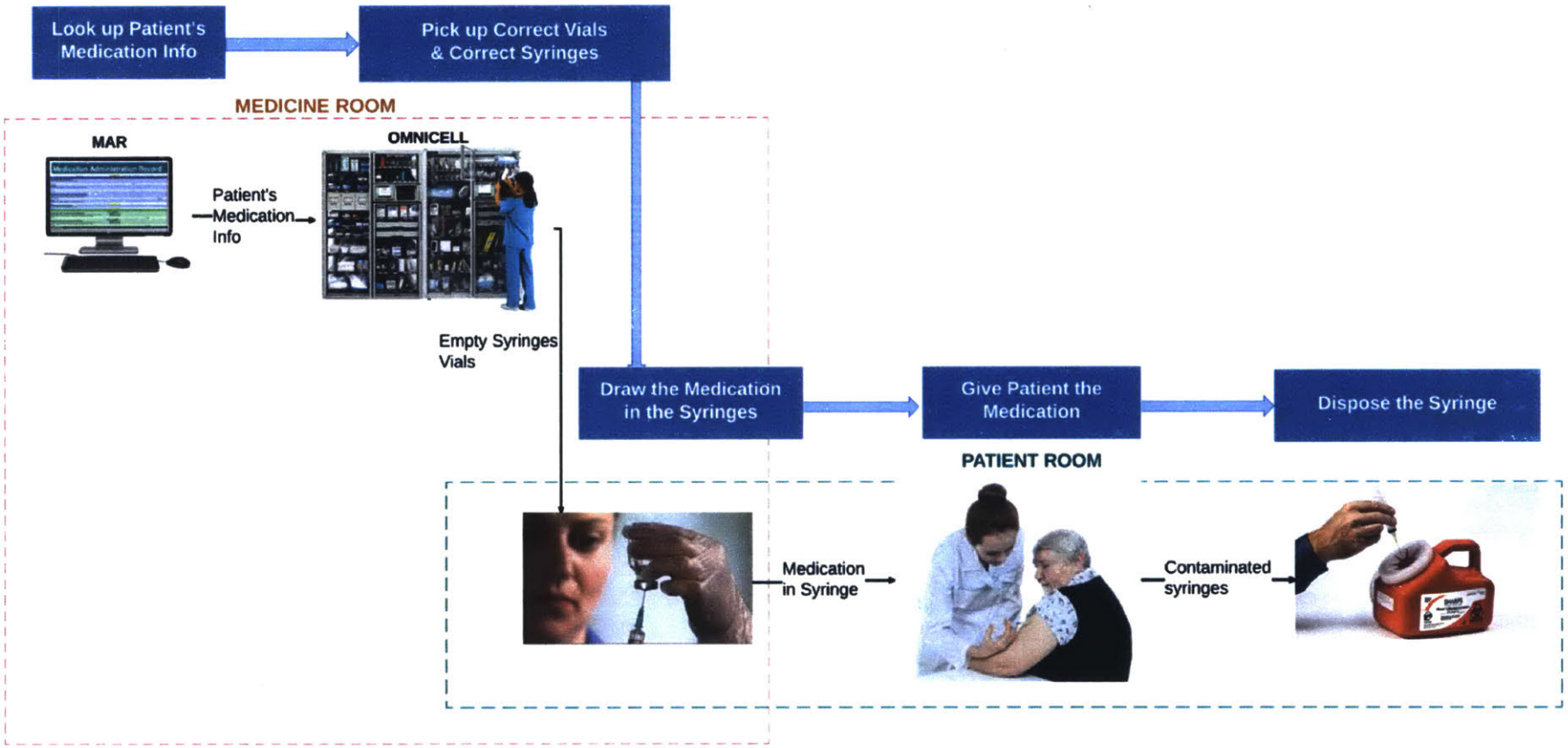

Figure 15: ConOps of the Operator (the nurse) using a Sharps Device

ConOps

The concept of operation is drawn to show different stages a sharps device goes through in a hospital setting. The example in Figure 15 shows the ConOps of sharps, specifically a syringe with a hypodermic needle.

In the beginning of the lifecycle of the sharps, the hypodermic syringe is prepared by a nurse (who also happens to be the operator). This is not always true as sometimes a nurse prepares the medication and the operator might be other nurses or doctors.

The next step in the lifecycle is the nurse looks up the desired patient's medication information in MAR system (Medical Administration Record). He/she then picks up the correct vial of medication, syringe and needle from Omnicell®. Omnicell® is a brand that stores the medication and medication supplies. ("Automated Medication Dispensing Systems | Omnicell," 2017).

The steps above are usually done in a medicine room or a quiet room. Next, the nurse assembles the syringe and needle if needed and draws up the medication in the syringe. This step is done either in the medicine room or in patient room, depending on the medication/procedure. Next the nurse, the operator, gives the medication to the patient, and disposes of the contaminated syringe in the sharps disposal.

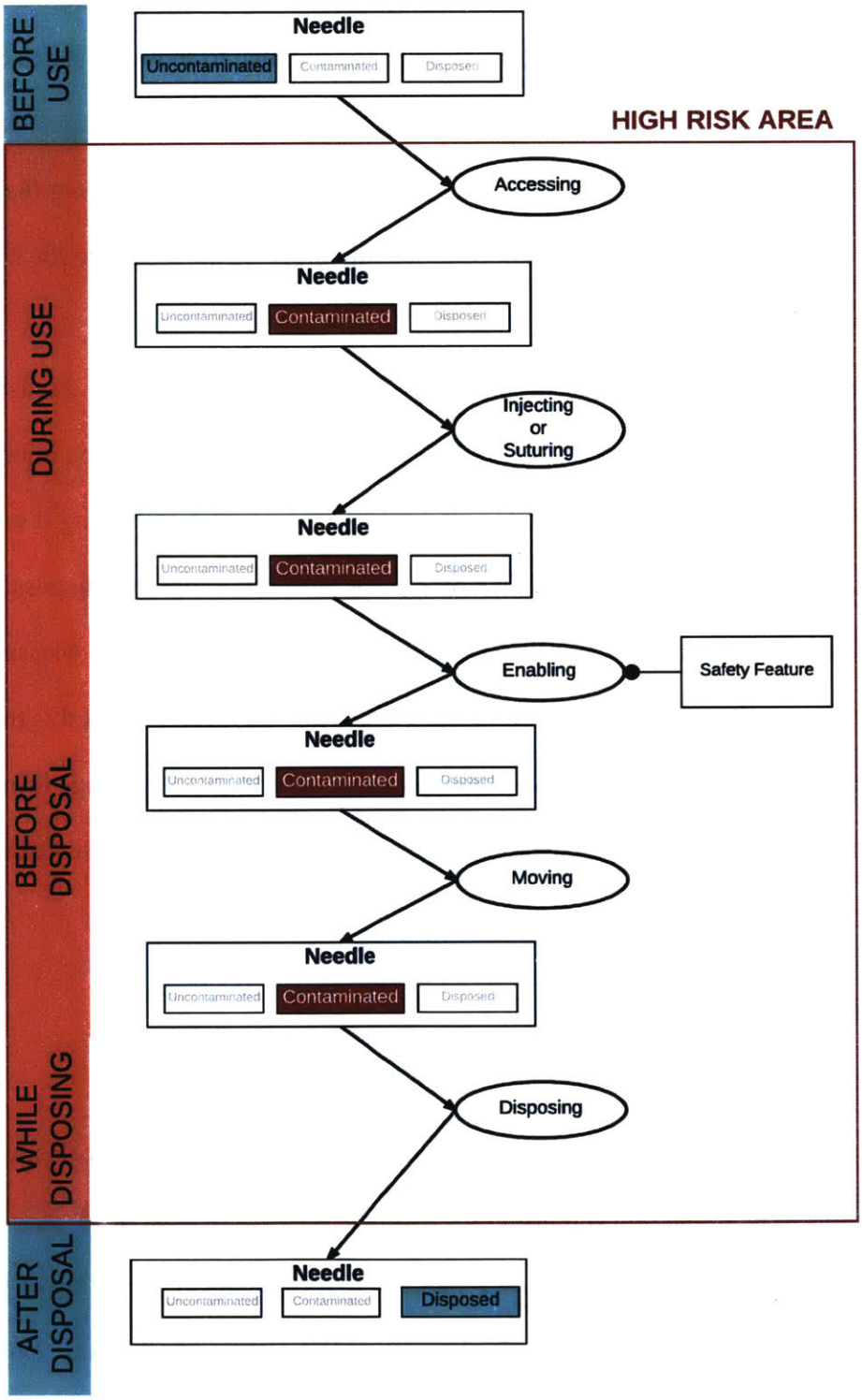

Figure 16: Various Status of Sharps with Needle

OPM

Using the ConOps, an OPM diagram (Figure 16) is drawn to show the status change of the sharps device (sharps with a needle). The OPM diagram consists of five stages: *before use of the sharps*, *during use of the sharps*, *before disposing the sharps*, *while disposing the sharps* and *after disposal*. The high-risk area of that needlestick injury occurs *during using the sharps*, *before disposing*, and *during disposal*.

Before the use of sharps stage, needlestick injury could happen, but no disease will be transmitted as the needle is uncontaminated. *After disposal* stage, there could be injury, especially if the disposal bin is full or there is improper disposal, such as leaving it in the patient's bed or tableside. However, the time period after disposal (improper disposal, device malfunction, or others) comprises less than 5% of the injuries according to the Massachusetts Sharps Injury Surveillance System data from 2013 and is not the focal point of this thesis ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016). However, that is an area that should be looked at for future work.

How Injuries Occur in the System

Interaction between the System and Environment

Using the existing system diagram (Figure 13), the initial causes of needlestick injuries are drawn on the system diagram (Figure 17).

The injury events such as 'collision', 'handling/pass equipment', 'moving or jarred device', 'manipulating needle into a patient', 'accessing IV', 'improper disposal', 'injury during disposal' are events caused by outside influences such as other co-workers, patient, or travel to

the sharps disposal. Other injuries such as 'during clean up', 'malfunction of safety engineered device', 'suturing', or 'recapping' are injuries that occurs within the system, meaning there is no external influences that cause the injury. The list of injury events/causes are from the annual report from Massachusetts Department of Public Health[10]. The bolder lines indicate the highest sharps injury causes in Massachusetts. The highest identified are, in decreasing order, 'suturing' (12%), 'handling/pass equipment' (12%), 'collision with sharps or coworkers' (12%) and 'improper disposal/during disposal' (11%) ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016). These range from 9-12% and consistently are the highest-ranking causes (Laramie MPH et al., 2009, 2012).

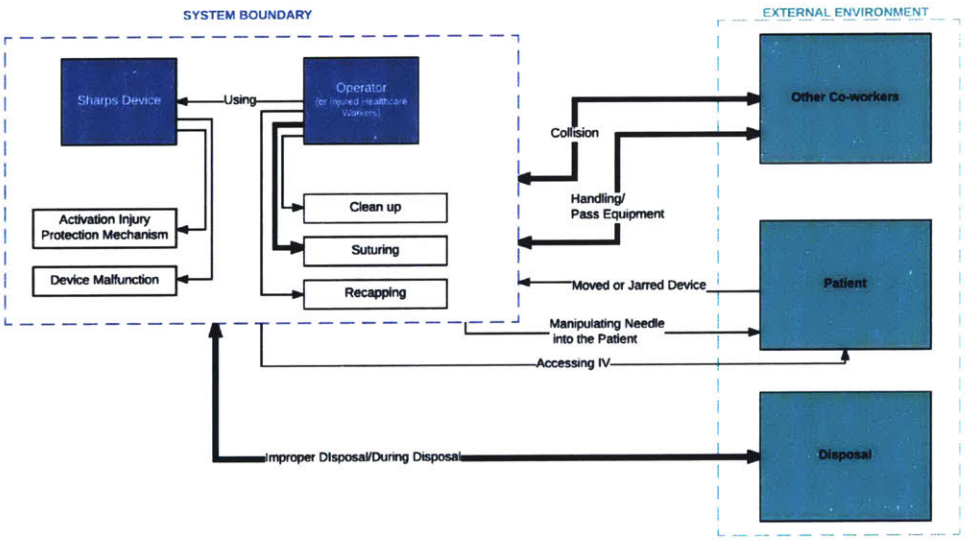

Figure 17: Injury Causes of Needlestick Injuries

[10] ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016; Laramie MPH et al., 2007, 2008, 2009, 2010, 2012).

Why Injuries Occur in the System

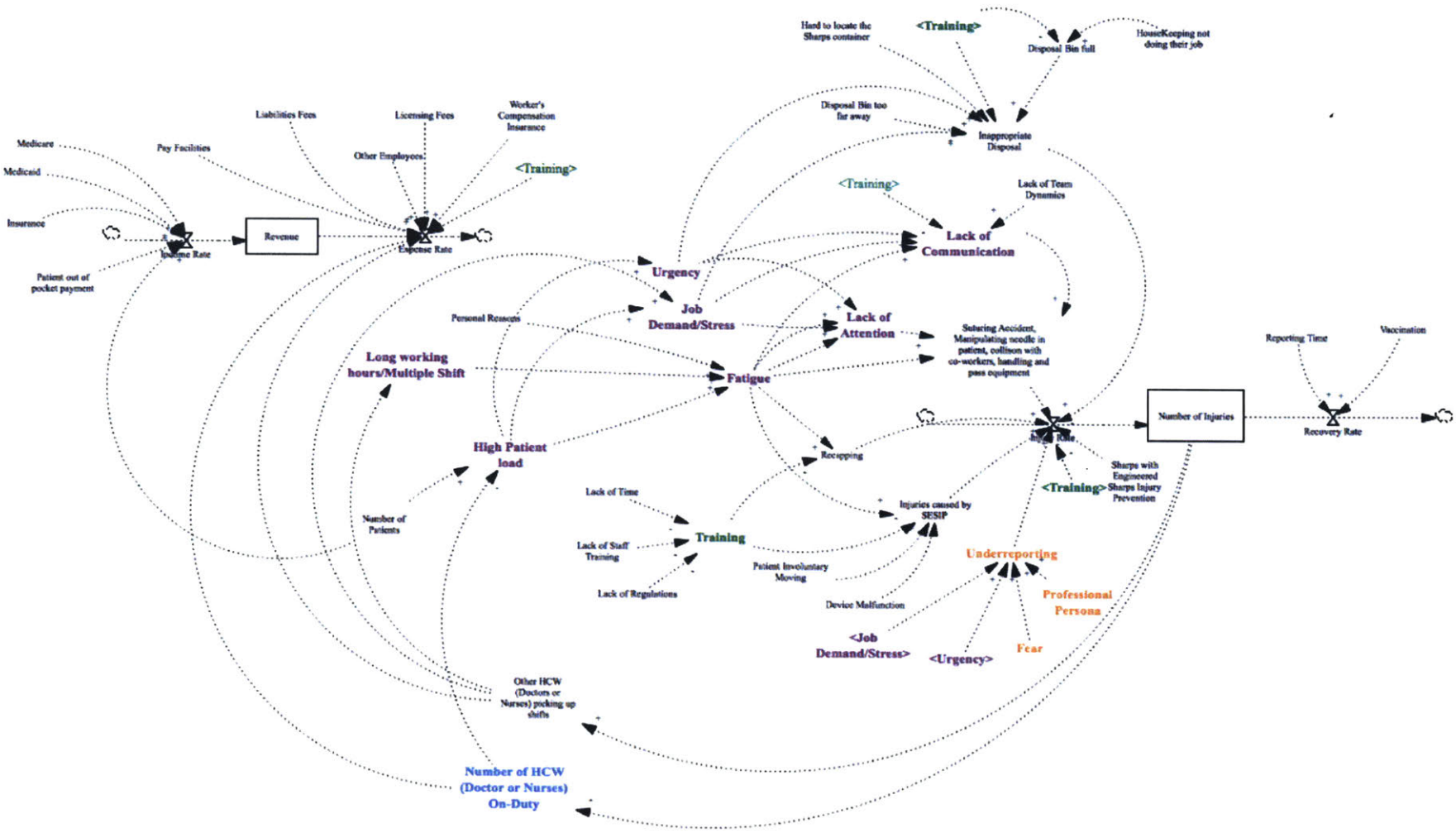

Figure 18: System Dynamic Model of Root Causes of Needlestick Injuries

System Dynamics

A system dynamics model is used in Figure 18 to show the root causes of why needlestick injuries occurs. Needlestick injury occurrence is a complex system, however the model/loop is used to represent the reinforcing loops, meaning loops that show needlestick injuries causes more needlestick injuries.

The initial situations that cause needlestick injuries are 'suturing', 'manipulating the needle in a patient', 'handle/pass equipment', 'collision with co-workers or sharps', 'accessing IV', 'recapping', 'safety engineered device malfunction', etc. ("Data Brief: Sharps Injuries among Hospital Workers in Massachusetts: 2013 Findings from the Massachusetts Sharps Injury Surveillance System," 2016).

But, these initial injuries are amplified by social causes such as long working hours, high patient load, (lack of) training, urgency, job stress, and fatigue. Social causes are the primary root causes of the injuries. Another unique root cause that does not cause needlestick injuries, but prevents needlestick injury report from accurately representing the actual injury numbers is underreporting. The details of the cascading effects of the social causes are explained in detail after the *Creation of System Dynamic Model: Stocks and Flows* section.

Creation of System Dynamic Model: Stocks and Flows

The system dynamics model is set up with two main stocks and flows.
The first stock is the number of injuries with inflow of injury rate equaling all the injury events minus the underreporting and prevention methods such as sharps engineered devices, training, etc. The outflow is the recovery rate, which consists of reporting time, and vaccination. Figure 19 shows the stock and flows of number of injuries.

The second stock and flows is the hospital's revenue. The inflow to the revenue is income rate which consists of payment from the health insurance companies, Medicaid, and Medicare multiplied by the number of patients (Note: the patient with no insurance is modeled in "Patient's out of pocket payment).

The outflow is the hospital's expense rate, which includes payment for facilities, liabilities fees, licensing fees, training, employee compensation, and worker's compensation insurance fees. Figure 20 shows the second stock and flows. Using the two main stocks and flows, the system dynamic model was created (Figure 18). Each loop is highlighted by a certain color and explanations of each loop is in sections below.

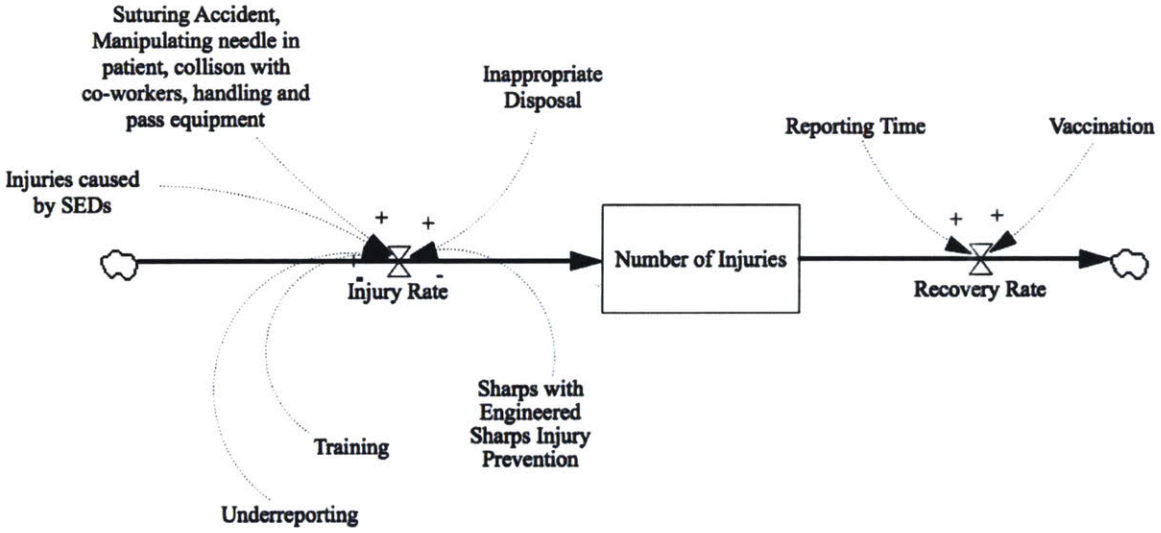

Figure 19: Stock & Flows of Number of Injuries

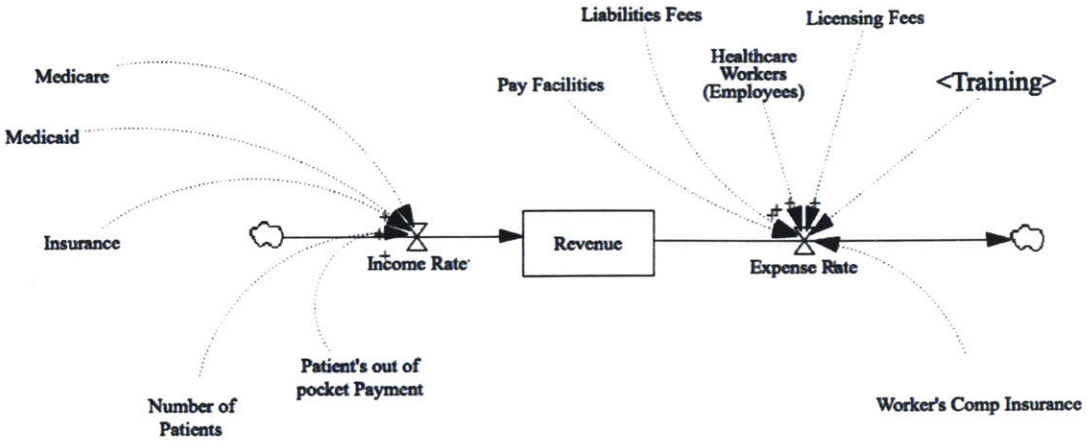

Figure 20: The stock and flows of Hospital's Revenue

Purple Loop: Secondary Effects of High Patient Load and Long Hours

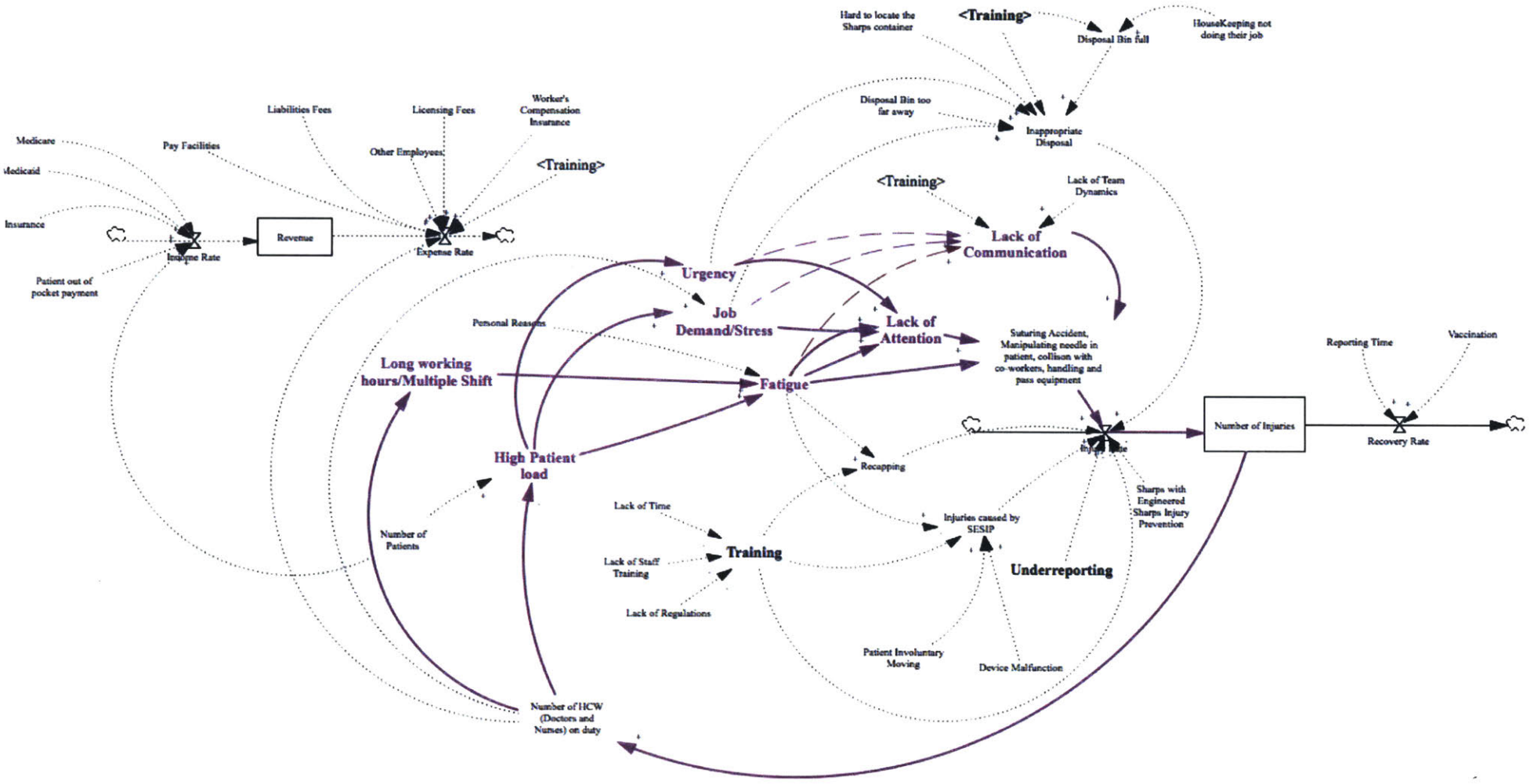

Figure 21: Secondary Effects of High Patient Load and Long Hours

Blue Loop: Root causes of Underreporting

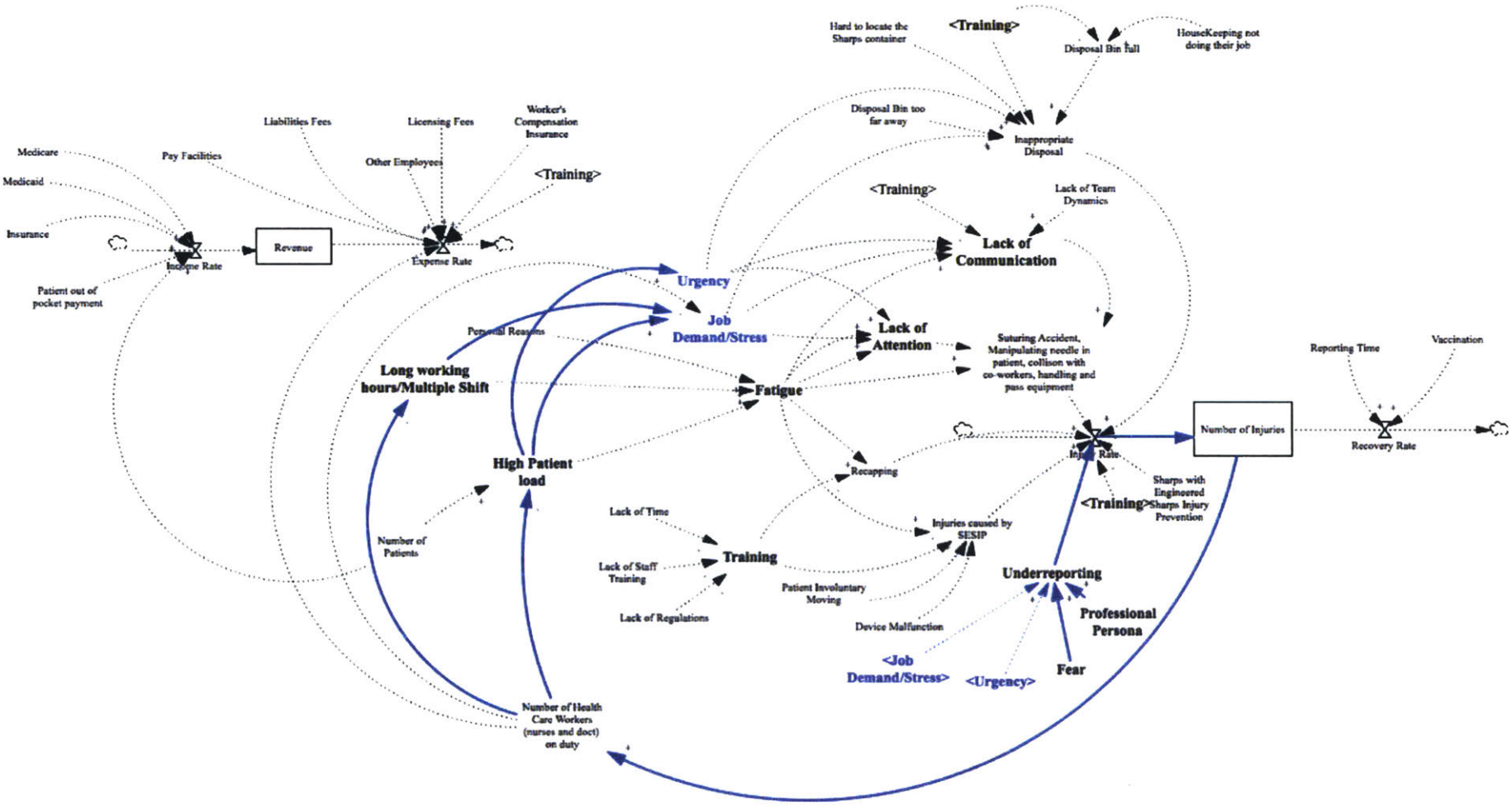

Figure 22: Root causes of Underreporting

Green Loop: Training

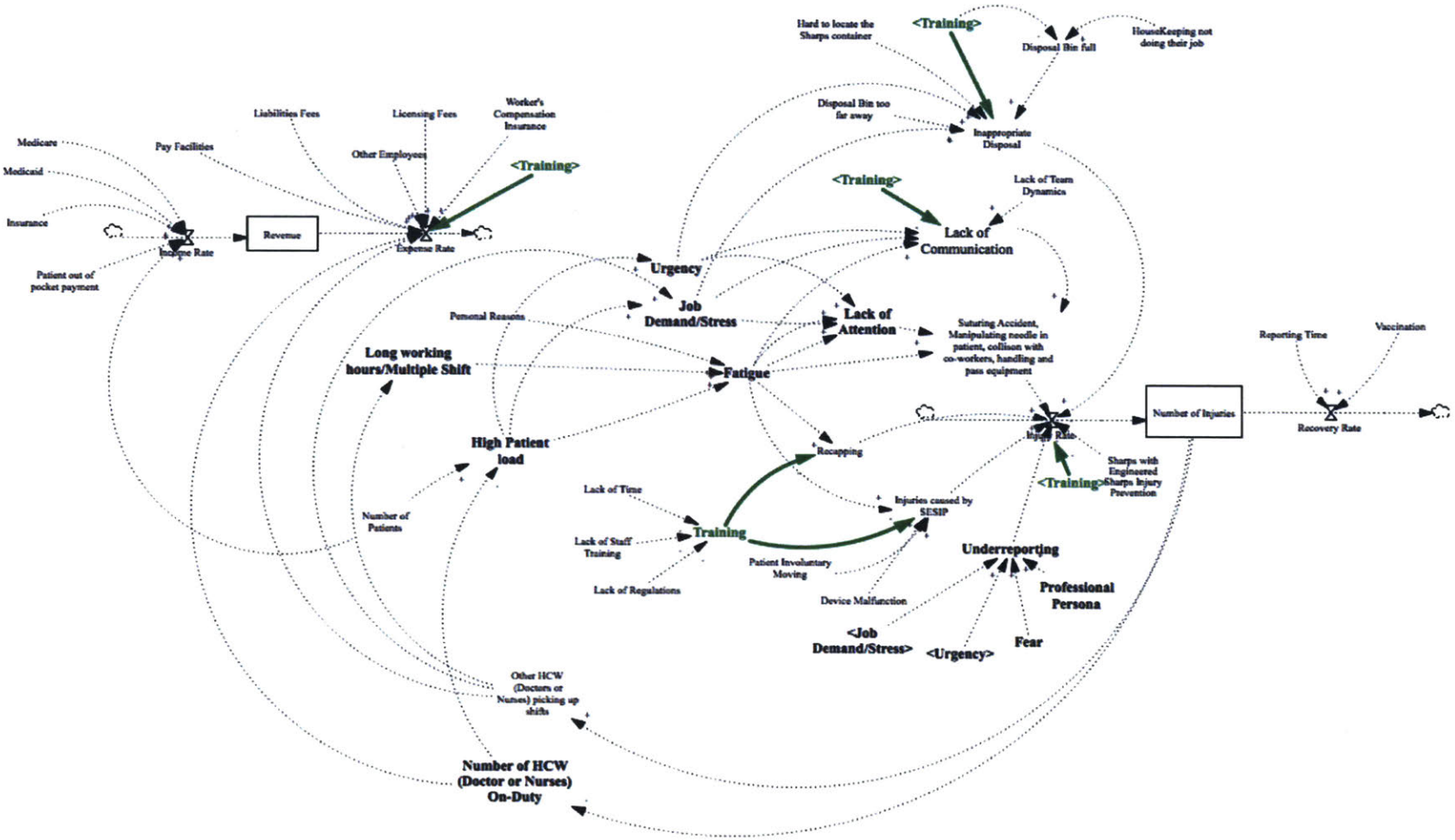

Figure 23: Training Influences

Purple Loop: Secondary Effects of High Patient Load and Long Hours

The purple loop (Figure 21) shows how the needlestick injuries affect the system by decreasing the number of healthcare workers (HCW), especially doctors or nurses on duty: either by having them take time out of their day for tests/treatment or taking days off due to the injury. Initially the decrease in the number of HCW on duty saves the hospital some money (as they are no longer paying the absentee nurse/doctor), however absence of a health care provider means the other doctors and nurses have to take over for that absentee doctor or nurse.

As the other doctors and nurses add extra shifts and hours, their fatigue level, job demand/stress, and urgency all increase. As the healthcare workers are stressed and fatigue and are trying to do their work with urgency, they will spend less time communicating. Lack of communication can cause sharps/needlestick injuries such as 'collision with co-workers' or 'sharps injury during handling and passing equipment'.

Urgency and job stress also causes lack of attention, which can lead to needlestick injuries such as 'collision with co-workers', 'suturing accidents', 'manipulating needle in a patient', etc. This loop of increase in patient load and long hours due to needlestick injuries causes more needlestick injuries, and therefore is a reinforcing loop.

Blue Loop: Root causes of Underreporting

Healthcare workers have the tendency to not report, which leads to incorrect representation of reported needlestick injuries data (CDC, 2015). Figure 22 shows the root causes of underreporting. Some of the root causes of underreporting are job stress and urgency. The healthcare workers might not want to take time out of their busy day from seeing patients to take care of their own injuries. The other root causes of underreporting could be fear of losing their job or self-perception of being viewed as incompetent. From the interviews, other root

cause of underreporting that is not covered in literature is professional persona, especially of doctors. The professional persona of doctors to be perfect and never to make mistakes leads to lack of reporting of needlestick injuries.

Green Loop: *Training*

The last loop in the system is related to Training (Figure 23). Lack of training can cause the healthcare workers to recap the needle after use, which they are not supposed to do, or make them more susceptible to injuries with safety engineered devices. Lack of training also affects the communication since if they are not trained to communicate well, accidents such as collision with other coworkers or during handling and passing of the sharps can occur. Lack of training can also cause inappropriate disposal of needles.

Training does add a cost to the hospitals' expense rate, however increase in training can help prevent or reduce some of these injuries.

How Needlestick Injuries Affect the Stakeholders

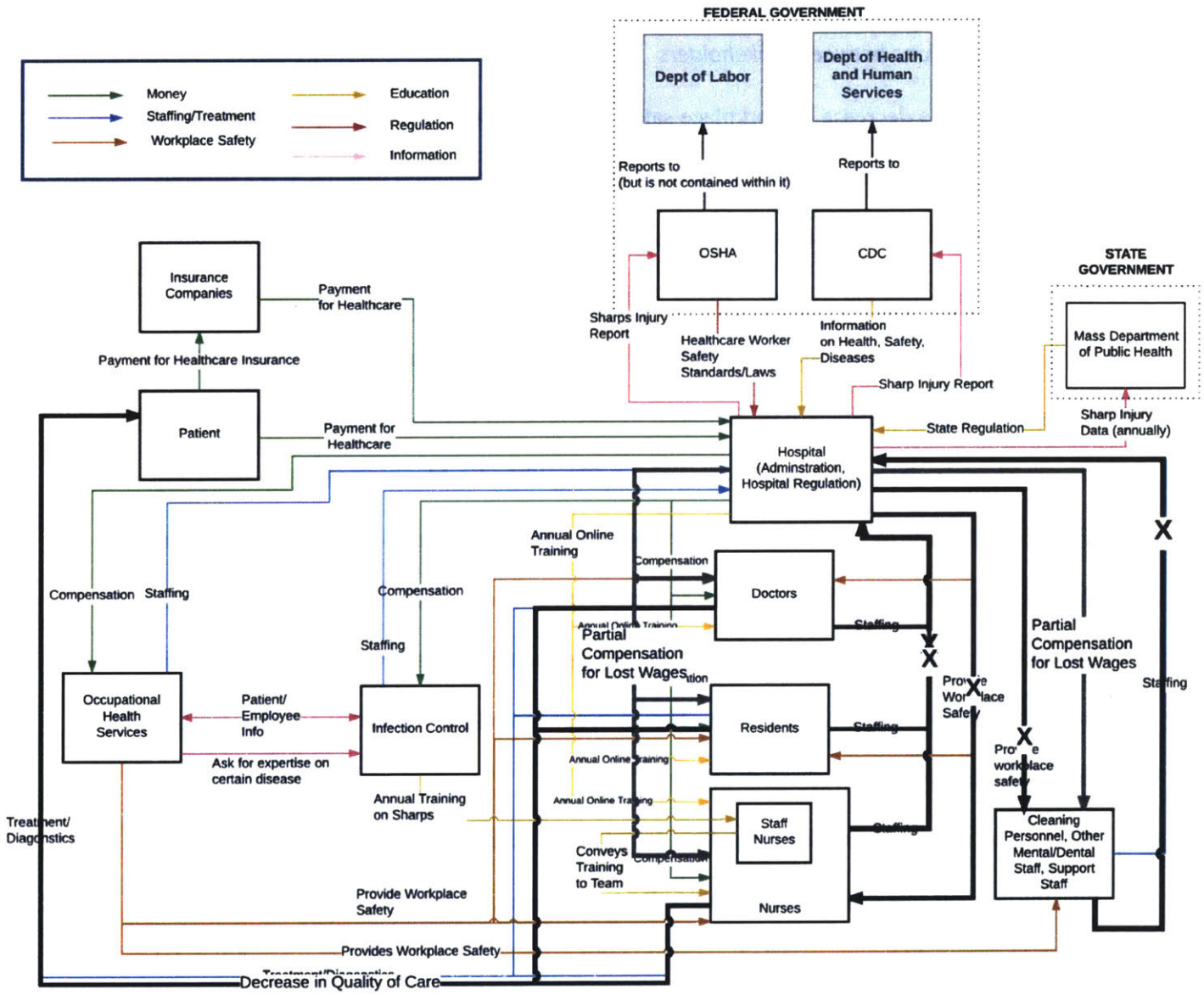

Figure 24: Stakeholder Analysis Changed due to Needlestick Injuries

Needlestick injuries break some connections between stakeholders from the Stakeholder Analysis. The four connections that are either broken or added to the Stakeholder Analysis are as

follows: 'decrease in workplace safety', 'potential decrease in staffing', 'decrease in treatment for patients', and 'partial compensation for the loss wages'.

Broken Connections between Stakeholders

There is a decrease in workplace safety when a healthcare worker gets injured. Under the Massachusetts General Laws c. 152, § 25A, employers are required to provide the workers' compensation insurance to all of their employees ("Employer's Guide to the Massachusetts Workers' Compensation System," 2014). If the needlestick injury has been reported within 5 days, the insurance takes care of the injured healthcare worker's treatment, testing, and portion of lost wages if the healthcare worker need to take time off due to the injury after first five days.

There is also potential of decrease in staffing if the healthcare worker contracts any diseases and needs to take time off from work. The decrease in staffing can lead to decrease in quality of care for the patients as there are not as many doctors/nurses as before, but more importantly other doctors/nurses have higher stress and urgency as they pick up the additional patients from the injured doctor/nurse. This increase in stress and urgency could potentially lead to additional accidents/needlestick injuries.

The quality of care for the patient is not only decreased during the decrease in staffing but also during first few days/weeks after needlestick injuries. During that time, the injured doctor/nurse could be preoccupied or worried if they contracted any diseases or of their job competency level is in question. All of this could lead to poor quality of care for the patient.

Effects on Hospitals

The needlestick injuries not the only effect the injured healthcare workers, but they also affect the hospital as an organization. The hospital is not only impacted by decreased in staffing and wellbeing of their employees' (healthcare workers), it is also impacted financially. The

hospital is stretching its current staffing resources and creating more information about needlestick prevention (through training or information posters), which adds cost, along with the cost of purchase of worker's compensation insurance.

VI. Discussion

For this thesis, the thesis question revolved around why needlestick injuries rates are not negligible with the current prevention methods. Needlestick injuries are injuries sustained by healthcare workers when they puncture their skin with a contaminated needle that has been previously used on a patient.

Needlestick injuries will never be completely eliminated as they occur in high stress, high pace environment and are being operated by humans. There are processes in place to reduce needlestick injuries such as work-practice control, engineering control, personal protective clothing and equipment, employee training, medical surveillance, hepatitis vaccinations ("Safety and Health Topics | Bloodborne Pathogens and Needlestick Prevention | Occupational Safety and Health Administration," 2017).

However, these processes do not address one of the primary root causes of needlestick injuries which emerged from the Patient-Centric Mental Model (See Figure 25). The proposed solution needs to be a combination of holistic and systematic improvements to reduce the root causes of needlestick injuries rather than focusing on one or two areas of improvements.

Patient-Centric Mental Model

There are two main components to needlestick injuries: the needlestick injuries and underreporting. The reported needlestick injuries are the actual number of needlestick injuries minus the injuries that are never reported (underreporting). To tackle needlestick injuries, both underreporting and the actual needlestick injuries need to be addressed.

Using literature review, interviews, and shadowing a nurse for a day, three main root causes of needlestick injuries stems from Patient-Centric Mental Model: professional pressure

(especially for doctors), high patient load/long working hours, and a safety culture focused primarily on patients.

Hospitals, clinics and healthcare services put high importance on patient-safety. However, having safety culture focused only on patients create other side effects.

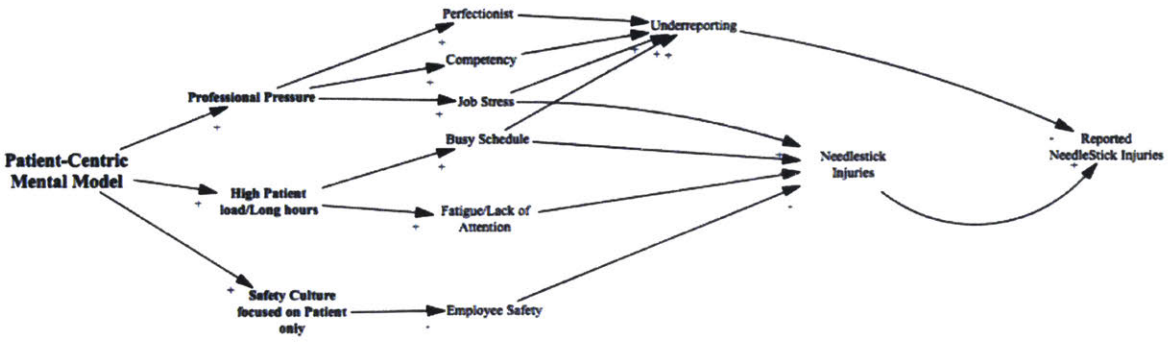

Figure 25: Secondary Effects of Patient-Centric Mental Model

Professional Pressure

Professional pressure is one of the root causes that stems from patient-centric mentality and affects primarily doctors. Professional pressure is felt by the doctors to be perfect and do everything fast. "There is a myth that doctors are supposed to be perfect and do everything. Of course, it is never true… but especially when you are resident, you are part of *that culture* and you are trying to be this *perfect person*" (Dr. M, personal communication, Apr 13, 2017).

This professional pressure creates the behavior of perfectionist, high competency, but also creates high stress for the healthcare worker. Being a perfectionist and high job stress can often lead to underreporting as the doctors might not want to admit their mistakes or feel reporting will reflect badly on them. High competency and high skill sets can lead to doctors doing their own self-assessment of risks and not reporting. If the doctor knows the patient does not have HIV, HepB or HepC, they won't bother reporting it.

High Patient Load/long hours

Another side effect that emerges from Patient-Centric Mental Model is high patient load. High patient load comes from financial pressure of hospitals. High patient load/long hours for doctors and nurses leads to busy schedule, fatigue and lack of attention. All of these are symptoms that can cause needlestick injuries. The busy schedule is also another reason why healthcare workers do not report injuries as they do not want to take time away from their busy day to report as it takes time away from their patients (Guglielmi et al., 2010).

Safety Culture focused on Patients only

The safety culture being focused on patients only and not on healthcare workers can lead to more injuries. In the interview with the OSHA Director, he stated "all the metrics from the leadership and insurance companies is patient infection [and] patient safety. OSHA looks at employee safety, but it is a secondary thing. We have 25,000 employees, we see 100,000 patients in a course of the year. That's the priority: patient safety" (Mr. A., OSHA Director, Personal Communication, Apr 10th 2017). Similar culture in mentioned in the literature as a staff nurse at Lattimore Community Surgicenter in Rochester, NY, discussed the culture of safety in her department. " 'A culture of safety' has been used by the health care community to let patients know that we are doing everything we can to care for them in a manner that will result in the most positive outcomes possible; however, that culture has not applied equally to the safety of team members caring for the patient" (Guglielmi et al., 2010).

Systematic Solution

In order to truly reduce needlestick injuries, a systematic solution that reduces all of the root causes of needlestick injuries needs to be implemented. Having a solution that focuses on only one or two areas of improvements will not eliminate needlestick injuries as there are multiple root causes of needlestick injuries.

The systematic solution consists of three paths

1st Path: Encourage Reporting

2nd Path: Reduce Professional Pressure and High Patient load/long hours

3rd Path: Focus on Healthcare Workers' Safety

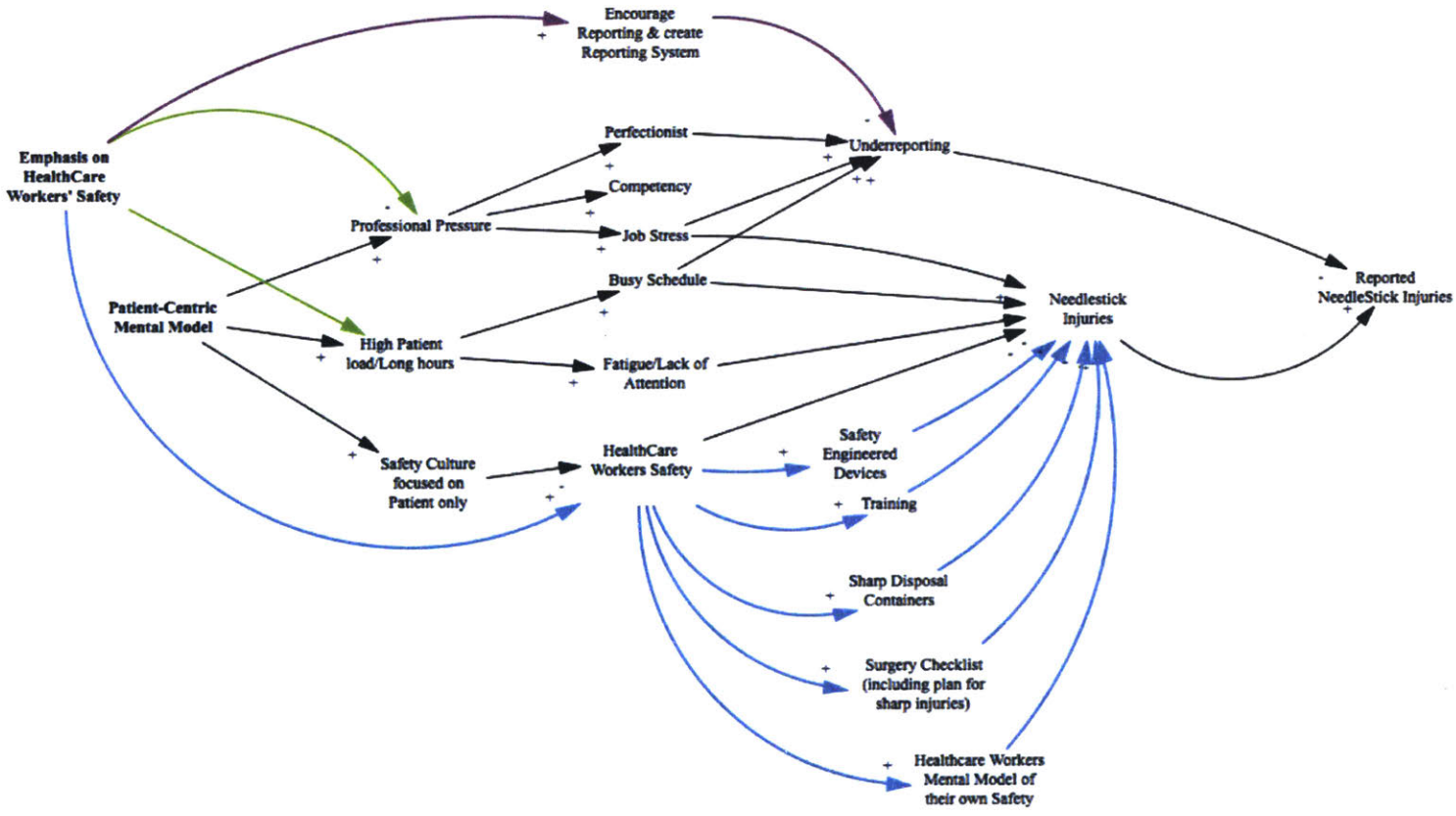

Figure 26: Systematic NeedleStick Solution

1st Path: Encourage Reporting

Even though, this path does not directly reduce needlestick injuries, reducing underreporting is critical for needlestick injuries. Underreporting is when a healthcare worker sustains a needlestick injury but does not report it. This lack of reporting creates a big void in the actual reported data, and causes the needlestick injuries data to underrepresent the actual number of injuries.

Therefore, if the actual number of injuries is not known, it is impossible to know the impact of different approaches to continuing reduction in needlestick injuries.

I also had an opportunity to shadow at the reputable hospital in Boston (Hospital A). This hospital stress the importance of reporting needlestick injuries. They provided their healthcare workers with an easy online injury reporting system. Furthermore, one of the nurses at that hospital mentioned that the hospital puts a high importance on healthcare workers' safety. Not only does the hospital encourage reporting of injuries, but the healthcare workers also do not fear that the reporting will affect their job performance.

Therefore, creating this culture of reporting by giving easy access to report, as well as giving the healthcare workers confidence that reporting won't harm their job performance, will reduce underreporting.

2nd: Reduce Professional Pressure and High Patient load/long hours

The interviewed doctor, Dr. M., mentioned the culture of professional pressure for doctors. However, when discussed, he also mentioned the cultural shift since he has been a resident. "There [has been] a big push in residency program [since I finished my residency in 2000/2001] ... to limit workhours, improve self-care and reduce level of fatigue" (Dr. M, personal communication, Apr 13, 2017). This shift in mental model of healthcare workers,

especially the doctors, gives way to reduce the professional pressure and high patient load/long hours.

As it takes time to change mental models, there is usually a delay. But focusing on addressing the root causes such as high patient load and professional pressure, needlestick injuries will eventually be reduced.

3rd Path: Healthcare workers Safety Culture

The third path to reduce needlestick injuries is to change the safety culture from patients first to patients *and* healthcare workers first. A focus on healthcare workers' safety creates multiple incentives that help with reducing needlestick injuries such as implementation of safety engineered devices, proper training, sharp disposal containers, surgery checklist and increase in healthcare workers' mental model of their own safety. Most of these are already introduced in hospitals through the current prevention methods.

However, introducing safety engineered devices without the appropriate training is not an effective way to reduce needlestick injuries. In the literature, it has been shown that healthcare workers still sustain needlestick injuries with safety engineered devices if appropriate training is not given.

In one of the journal articles published in 2016 showed that healthcare workers still sustain needlestick injuries while using safety engineered devices (SEDs). They surveyed 533 healthcare workers who sustained needlestick injuries in Germany. "The [survey] results indicated that the acquired skills [on safety engineered device proper usage] are inadequate as one-third of the SED users had taken part in an SED training session [12 months prior to their injuries]" (Dulon et al., 2016).

In order to improve healthcare workers' safety, training needs to be offered not only on proper use of safety engineered devices, but also on needlestick injuries, prevention methods, reporting process. If the safety engineered devices aren't being used on a regular basis, the healthcare workers will forget the proper usage. Therefore, repeated training would be helpful. The training can be done in person or put online so the healthcare workers can access it whenever it is needed.

While shadowing at the hospital in Boston, I asked one of the clinician nurses on her experience with needlestick injuries and how the process has changed over the years. The clinician nurse has been practicing medicine for over 40 years and she mentioned 20/30 years ago, there might be one or two sharps disposal bins on the whole floor. So, the nurses would have to carry the contaminated needles in their pockets while visiting patients until they get to the sharps disposal bin. Today, there is a sharps disposal bin in every room, including on an emergency cart.

It is not only important to improve the engineering control, but also to make the healthcare workers think consciously about sharps prevention. This is related to sharps injuries in general. I talked to a surgical resident while shadowing at the hospital. The resident mentioned that sharps prevention was included in their "time-out" surgical safety checklist in that hospital.

Surgical safety checklist is a checklist developed by World Health Organization along with Harvard School of Public Health to decrease errors and increase teamwork/communication in surgery ("WHO | WHO Surgical Safety Checklist," 2014). The checklist is done prior to medical procedure and is a way for the whole team to participate and be on the same page. By including a question on the checklist on how sharps are being handled will make the surgeons and nurses consciously think about sharps/needlestick safety.

The final implementation is changing the healthcare workers' mental model of their own safety. This is no easy task. "The nurses and [the doctors] are so busy of doing what they are doing for the care of the patient, they are not thinking the risk to themselves... the last thing [healthcare workers] think about is about their own safety in healthcare...I think [needlestick injury] is important. Anything you can do to raise awareness. I think, it is awareness, but I don't know if it changes [healthcare workers'] perspective" (Mr. A., OSHA Director, Personal Communication, Apr 10th 2017).

While talking to the surgical resident during shadowing, he mentioned that there is a question on how sharps will be handled during the surgery on the surgical checklist. He said his team jokingly says "safely". The resident also discussed there are so many things they have to think about and sharps prevention is yet another thing. But, having the awareness such as having it on the checklist is important to get doctors and nurses to think about it even if it does not change their behaviors right away.

Pulling from Other Disciplines

Other disciplines/industries that put high importance on employees' safety are discussed below. The interviewed OSHA Director, Mr. A., is also in the Army. He discussed the importance of safety in military. "Every time I go to the firing range, I am thinking I have a loaded weapon, I need to be extra safe." They are mentally trained to be extra cautious while using their weapons, even at a firing range.

Similarly, in fields such as the semiconductor industry there is a high importance on customer delivery and customer satisfaction but also a high importance on employees' safety. For example, a company that specializes in Implanters, which uses toxic gases. Any time there is a gas bottle change in the clean room, strict protocols are followed. The technician who is

changing the gas bottle will inform everyone in the clean room of the bottle change. He/she will wear protective body gears and fence off the bottle change area. He/she will also get another technician as the protocol is to use two-person during bottle change.

Examples from other industries show that it is possible to balance customer satisfaction with employees' safety but it requires process change and mental model change.

Future Work

For future work, it would be ideal to look at a hospital that has good implementation of needlestick injury prevention and compare their needlestick injury data with the state data. The data over the years can also be looked at while mapping process change. It is important to note, there might be a delay in the process implementation and the needlestick injury reduction.

Other future work could focus on the overlooked stakeholders such as housekeeping staff and food nutrition services. The work could include investigation on how the overlooked stakeholders are being trained on needlestick injuries and what are the process implemented to help them from needlestick injuries. "Doctors, nurses, they are participants in this process [needlestick injury prevention]. [But] there are people downstream that are victims, that have no role in this [such as] someone in the linen department, a nurse leaves needle in the sheets. Or food nutrition services, someone leaves in the food stray. That to me, no matter how much technology you develop, it is not going to change" (Mr. A., OSHA Director, Personal Communication, Apr 10th 2017).

Finally, the future work could be validation of the system dynamics model. Currently, the system dynamics model was created to illustrate concepts, but it would be beneficial to have a working model.

VII. Conclusion

Nurses, doctors, EMTs, nurse practitioners, all decide to pursue healthcare primarily to help other people. However, helping other people should not be at the expense of their own health. According to the CDC, 385,000 needlestick injuries and other sharps-related injuries are sustained by hospital-based healthcare workers each year in U.S. (CDC, 2015). Needlestick injuries can impact healthcare workers' physical health (disease transmission of HIV, HBV and HCV) and their psychological health (depression, fear, low self-esteem).

Needlestick injuries will never be completely eliminated as they occur in high stress, high pace environment, but they can be reduced significantly if the solution focuses on systematic approach that reduces the root causes.

This thesis question revolves around the reasons why the current prevention methods were not eradicating needlestick injuries. By using system thinking, current literature, stakeholder interviews, and knowledge from shadowing at one of the reputable hospitals in Boston, a systematic solution is proposed.

The proposed solution focuses on reducing needlestick injuries by addressing the root causes of needlestick injuries: professional pressure, high patient/long hours, and patient-centric safety culture as well as underreporting.

The solution shows three paths to address the root causes. The first path is to reduce underreporting. Even though, underreporting does not directly cause needlestick injuries, it creates a big void in the reported injury data. Therefore, if the actual number of injuries is not known, any reduction in needlestick injuries cannot be properly measured.

Underreporting can be reduced by creating a process for healthcare workers to report. It is also important to encourage the healthcare workers to report and create a culture where they feel comfortable reporting and do not fear any job repercussion from reporting.

The second path focuses on reducing the professional pressure and high patient load. The doctor who was interviewed, Dr. M., mentioned a push in residency programs to encourage self-care and to limit residents' work hours. The same mentality needs to be applied to healthcare workers.

The final and third path is changing the mental model of patient first safety culture, to safety culture for patients *and* healthcare workers. Healthcare workers are wired to put patient first, moving that perception from patients first safety culture, to patients *and* healthcare workers, is an integral part of the systematic solution.

A holistic solution is needed for a complex problem such as needlestick injuries. Only with a systematic solution that focuses on all of the root causes of needlestick injuries can needlestick injuries truly be reduced to a negligible amount.

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