OCCUPATIONAL EXPOSURE TO BLOOD &

BODY FLUIDS IN U.S. HOSPITALS:

IMPLICATIONS OF NATIONAL POLICY

by

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DEDICATION

to

My Mom - Jane Culwell Hogan - and the Generations of Nurses in my Family

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Lastly, thank you to healthcare practitioners, as the world would not turn without you. Be well. Stay safe.

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Occupational exposure to blood and body fluids (BBF) is a major concern in healthcare, because of the risk of occupationally-associated infections (OAIs). In 2000, the Needlestick Safety and Prevention Act (NSPA) required OSHA to incorporate additional requirements to protect healthcare workers (HCWs) from exposure to BBF. As a nation, we saw needlesticks or percutaneous sharps injuries (PCSIs) decline, but it is uncertain if the decline also represented declines in other BBF exposures, specifically mucotaneous splash and splatter incidents (MSSIs).

This study measures the implications of the NSPA and its incorporation into the OSHA BPS by determining whether the ratio of MSSIs to PCSIs (MSSI:PCSI) varied over three study periods: 1995-1999 (prior to NSPA), 2000-2002 (NSPA and OSHA promulgation), and afterwards, in 2003-2007; these comparisons were also made between high and low risk hospital areas.

Over 30,000 exposure incidents from nearly 70 U.S. hospitals reporting into the Exposure Prevention Information Network (EPINet™*) were analyzed. Preliminary analysis of MSSI:PCSI indicated no difference by time period. Ratios were higher in low risk (*e.g.*, patient rooms, radiology) compared to high risk hospital areas (*e.g.*, operating room, obstetrics).

Because personal protective equipment (PPE) protects workers from MSSI exposures, PPE use was also analyzed for all MSSIs across the study period. Counts and percentages were calculated for high versus low risk areas. For MSSIs, there was more frequent (75%) and a higher odds of PPE use (OR = 1.58, CI 1.35, 1.72) in high risk areas, as compared to low risk hospital areas (25%). The majority of MSSIs involved the eyes (79%) as compared to the nose (6%) and mouth (15%). Sixty-six percent of those incidents occurred in high risk areas.

Additionally, appropriate incident-specific PPE use was analyzed and compared, meaning when eye incidents were identified, so was use of eye-appropriate PPE (*e.g.*, eyeglasses, side shields, faceshields or goggles). Masks (31%) and eyeglasses with sideshields (26%) were most frequently worn appropriately in high risk areas, as compared to low risk (12% and 8% respectively). The odds of appropriately wearing masks (OR=1.41, CI 1.63-1.82) and eyeglasses (OR=1.97, CI 1.78, 2.57) were also greater in high as compared to low risk hospital areas. Eye-appropriate PPE was worn most frequently (65%) in high risk areas than other types of PPE type (nose or mouth) (5%).

The results of this study suggest that, despite passage of a national policy and a decline in sharps injuries, there has been little change in the overall ratio of MSSIs to PCSIs. There are, however, differences between MSSI and PCSI in low compared to high risk hospital areas. HCWs working in low risk areas are not wearing PPE as frequently and appropriately as those in high risk areas, despite experiencing an MSSI. This study suggests that, whereas additional policy may not be necessary, perhaps a greater focus on preventing exposure incidents in low risk hospital areas is needed.

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PUBLIC HEALTH SIGNIFICANCE

U.S. Workforce Impact

Nearly 20 million members of the U.S. working population are employed in healthcare settings and the healthcare sector will generate 3.2 million new wage and salary jobs by 2018 (Bureau of Labor Statistics 2012). This sector of the workforce represents the largest segment of employment growth in the U.S. and serves the largest proportions of Americans, ensuring proper and timely diagnosis, treatment, and care. Healthcare employment is marked as the industry sector with the largest growth (2.4%) over any other sector (BLS 2007).

In light of the current national economic environment and immediate reform of the healthcare system along with new demands placed on it, it is vital to keep workers in healthcare - and those specifically providing direct patient and acute care - well and working in order to ensure the vitality of those seeking care. Most recent data shows that there are over 35 million patient discharges per year (both living and deceased) in the United States from short stay hospitals (NCHS 2010). This comprises approximately 10% of the total U.S. population (Census 2009). Of those patients admitted, at least 185,000 are HIV-positive (NCHS 2007) and 46 per 1,000 are colonized or infected with methicillin-resistant *Staphylococcus aureus* (MRSA) (Jarvis 2007). HIV is only one bloodborne pathogen and MRSA is only one multi-drug resistant organism. There are many others with the potential to cause human disease, including bloodborne pathogens such as hepatitis B and C, syphilis, and viruses such as influenza, smallpox, West Nile virus, and others; and bacteria such as streptococcus, *Clostridium difficile*, and others.

Given that over 5% of Americans work in healthcare and over 10% of Americans will be admitted to an acute care facility, a substantive portion of the U.S. population contributes to the potential risk pool of occupational exposure to infectious diseases spread through splashes and splatters of blood and body fluids. As established by both BLS and OSHA, prevention of occupational injuries and illnesses among healthcare workers ensures the best work efficiencies (*e.g.,* reducing days away from work, increasing job ability and task completion, ensuring a viable healthcare staff-to-patient ratio, etc.) through the continuity of public and private care.

Exposure Impact

A major occupational health risk to healthcare workers is occupational exposure to viruses, bacteria, and other microbes that can cause manifestation of disease (occupationally-associated infections or OAIs) among healthcare workers who experience exposure incidents (*e.g.,* those relating to skin and mucous membranes or "mucocutaneous") (Marcus 1988, Klevens 2007). Occupational mucous membrane exposures (including face, nose, and mouth) to blood and body fluids from patients infected with bloodborne viruses (*e.g.,* HIV, HBV, HCV) are especially high risk, creating essentially an infusion of infected fluid from patients through the membranes of healthcare workers. The population of acute care co-infections is on the rise. Community-associated MRSA (CA-MRSA) infection is six-fold higher among HIV-positive patients (996/100,000) and significantly increasing since 2000 (Popovich 2010).

Because of the potential fluid to membrane infusion of microbe-rich body fluid, splashes and splatters may create a higher disease burden of significance than contaminated sharps injuries or needlesticks. Available studies demonstrate that eye, nose, and mouth splashes and splatters occur more frequently among surgeries, in catheter laboratories, during dental procedures, in orthopedics and obstetrics, in emergency departments, and in emergency field situations (Purro 2001, Jagger 1994, Maritsa 2012, Mbaisi 2013), and in medical wards at the patient's bedside (Alamgir 2008). In international publications, reports are most frequent for occupational exposure to blood versus other body "liquids" meaning that global communities associate a greater risk of a viral/infectious load/dose associated with blood versus another body fluid (Maritsa 2012).

The psychological and emotional burdens and costs related to occupational exposures to blood and body fluids are wide reaching. Burden and cost include not just actual bacterial or viral seroconversions to bloodborne viruses like hepatitis B virus or manifestation of an MRSA infection through contact exposure and others, but also side effects from medical prophylaxis, time away from work, potential mandatory furloughs, staffing shortages, psychological distress, administrative controls related to work and others (OSHA 1992, 2000; CDC 2009).

Impact of Personal Protective Equipment (PPE) Use

Personal protective equipment (PPE) prevents exposures described above, but compliance with its use (Gershon 1995) and availability (Afridi 2013) are marginal. A longstanding problem in disease prevention and infection control, specifically for occupational exposures, has been poor adherence to universal precautions and poor compliance with usage of personal protective equipment (PPE) not just in the United States, but throughout the world (Zafar 2006, Jagger 2008, Lal 2007, Phillips 2007, Afridi 2013, Yousafzai 2013, Mbaisi 2013). These potentially hazardous behaviors are negatively affected by poor training; little understanding of disease transmission (Naghavi 2009); poor comprehension of occupational risk (Gershon 1995, Krishnan 2006); unavailability and inappropriate selection of PPE (Matthews 2008, Sacchi 2007, Afridi 2013); selection of uncomfortable or burdensome PPE (Perry 2003); high pressure or unexpected situations (Jagger 1994. Maddan 2002); and an overall risk-taking personality or complacency among healthcare workers (Gershon 1995). Jagger et al. illustrate that, out of 367 blood and body fluid (BBF) exposures reported through EPINet, 74% of cases were not wearing protective equipment such as goggles, face shields, or eyeglasses with side shields (1998). Additionally, Sacchi et al. demonstrated that in almost half of the splash and splatter incidents in an obstetrics setting the worker was not wearing any personal protective devices (Sacchi 2007). There do not seem to be differences in developing countries like Kenya where obstetrics and gynecology represent the hospital departments/areas with the highest numbers of blood and body fluid exposures and where access to preventive or protective measures are inadequate (Mbaisi 2013). Operating room personnel have poor compliance with PPE use, as few as 32% wear glasses and 24% wear no eye protection (Akduman 1999).

Given the barriers of PPE use in the published literature, it is important to enumerate splash and splatter exposures to healthcare workers and to add to the body of evidence in order to better scientifically support suggestions for appropriate PPE use and preventive strategies.

Incidents of eye exposures also occur even when protective eyewear is worn. Incidents occur when body fluids squirt under pressure, when goggles slip, or when there is no protective cover for the eyes (*e.g.,* loose face shield) (Bentley 1996). "While most surgeons make an effort to avoid needlestick injury, some can pay little attention to reduce the potential route of infection occurring when body fluids splash into the eye. It has been shown that transmission of HIV, hepatitis B or C can occur across any mucous membrane," states Davies et al (Davies 2007). In the study performed, the researchers' aim was to quantify how frequently body fluids splash the mask and lens of wrap around protective glasses thus potentially exposing the surgeon to infection. Of 384 operations performed, 174 (45%) showed blood or body fluid splash on the lens of the eye protection worn during the procedure. A high incidence of exposure (79%) was found during vascular procedures and all amputations showed splashes on the protective lens. The authors note interestingly that 50% of laparoscopic cases resulted in blood or body fluid splash on the protective lens. The authors conclude that, with a higher prevalence of people living with infectious and bloodborne diseases, usage of protective eye equipment is more prudent than ever (Davies 2007). This study is one of few published that illustrates the degree of effectiveness of PPE worn by healthcare workers in surgical settings. It provides evidence in today's healthcare environment that *appropriateness* of selection of PPE is important for preventing exposures. Again, studies as recent as 2013 indicate that the PPE selection picture is no different in emerging or developing countries throughout the world like Kenya, Pakistan, or Thailand (Mbaisi 2013, Chaiwarith 2013, Afridi 2013).

Policy Implication

The risk of occupational exposure to blood and body fluids in healthcare settings remains high over three decades of national awareness through campaigns, policies, regulations, and guidance from agencies like the Centers for Disease Control and Prevention (CDC), the National Institute for Occupational Safety and Health (NIOSH), and federal enforcement of the Bloodborne Pathogens Standard (BPS) through the Occupational Safety and Health Administration (OSHA). Professional associations, unions, private sector partners, and worker advocacy groups also remain active and engaged in both national policy and clinical practice realms.

Over the last five years, there has been swelling activity in federal, state, and local policy and legislative action regarding healthcare-associated infections including not just bloodborne pathogens, but airborne, vector-borne, and contact-transmitted pathogens (*e.g.,* MRSA, VRE, c. *difficile*). Policy has been driven by data published that shows healthcare-associated infections among patient populations account for more than 99,000 deaths nationally (Klevens 2007). However, it is unclear how many healthcare-associated infections among healthcare workers there are, specifically those caused by occupational exposure to blood and body fluids and as such, there is little movement in occupational health policy in worker health environments. There are no studies published that focus on the impact a national policy had on occupational mucotaneous exposures compared to percutaneous exposures and EPINet provides a unique opportunity to do such.

Summary

Given that the healthcare sector is growing and that occupational eye, nose, and mouth exposures to blood and body fluids occur in 18-50 percent of the healthcare worker population (Davies 2007, Puro 2001, Reis 2004, Mbaisi 2013), studying exposures that have occurred in this decade is important to describe and learn from in order to add to the currently underwhelming body of literature. Workers in healthcare represent the largest work sector in the U.S. (BLS 2007); infectious disease burden of patients is high (NCHS 2007, Jarvis 2007); mucus membrane exposures to blood and body fluids are of high or unknown risk (Jagger 1999, CDC 1996); and PPE compliance as a protective measure is low (Zafar 2006, Jagger 2008, Lal 2007, Phillips 2007, Afridi 2013). Consequently, there is a high level public health impact and need for research to drive action. It is important to describe occupational exposures to blood and body fluids in order to contribute to the international dialogue on appropriate public and occupational health action. Even in the global literature, studies published as recently as 2013 indicate that "assessment of the danger… (is one of) the key elements for reduction of (blood and body fluid) exposure among health care workers" (Maritsa 2012). While assessing "danger" is important, it is also well accepted that under-reporting of exposures paints a more faded picture of risk in the U.S. and globally. A 2012 study assessing risk for exposure to blood or body fluids in Greece estimated that only 34.1% of study participants (nurses and physicians) actually reported an incident to the infectious disease/infection control committee (Maritsa 2012)

The current literature has significant gaps. There are no comprehensive, intentional, focused studies that evaluate and measure the occupational impact that splashes and splatters have on healthcare workers and compare them across high and low clinical care risk categories. Nor has there been a scientific analysis to determine appropriateness of eye and face personal protective equipment use. Studies published over the past 20 years have described splashes and splatters as ancillary and lower risk than contaminated sharps injuries, but without counting and measuring them directly and focusing on them as a primary research question, they will remain ancillary and mis-defined without scientific justification. It is the intent of this study to assess the degree of risk associated with mucotaneous exposures to identify whether the issue has merit and warrants more focused attention as a public health concern.

SPECIFIC AIMS AND STUDY QUESTIONS

The aim of this research study was to examine the epidemiology and describe the occupational risks associated with exposure to splashes and splatters of blood and body fluids (BBF) to the eyes, noses, and mouths of healthcare workers working in acute care hospitals. In order to determine whether mucotaneous splash and splatter incidents (MSSIs) are significant, they were compared to occupational exposure incidents that receive far more national attention, percutaneous sharps injuries (PCSIs).

To accomplish this aim the following hypotheses were tested.

- *The ratio of reports of MSSIs to PCSIs was higher in high risk hospital areas than in low risk hospital areas over the time period 1995 to 2007.*
- *Healthcare workers who experience an MSSI wear personal protective equipment more frequently in high risk hospital areas than those in low risk hospital areas.*
- *Healthcare workers who experience an MSSI wear appropriate personal protective equipment more in high risk hospital areas than those in low risk hospital areas.*

To answer these questions, data from the University of Virginia International Healthcare Worker Safety Center's Exposure Prevention Information Network (EPINet™*) EPINet™ was used for the thirteen-year timeframe from January1995 through December 2007 An "exposure" is defined as an EPINet™ reported incident of splashes or splatters to eyes, nose, or mouth (i.e., MSSIs). MSSI exposures were those occurring with or without the use of personal protective equipment (*e.g.,* goggles, glasses with face shields, masks), whereas PCSIs were defined on the basis of a report on the EPINet™ "*Needlestick of Sharp Object Injury*" Report Form.

Hypothesis 1: The ratio of reports of MSSIs to PCSIs was higher in high risk hospital areas than in low risk hospital areas over the time period 1995 to 2007.

While there has been extensive research on PCSIs in healthcare settings, little research has focused on MSSIs. Currently there is not a large evidence base to identify the risks associated with MSSIs. Of the studies published in the last decade, nearly all describe splashes and splatters as a background exposure compared to needlesticks (Adesunkanmi 2003, Puro 2001, Lal, 2007, Reis 2004). And while splashes and splatters are under-researched they may be potentially higher risk than thoroughly researched sharps injuries due to known biological factors and interactions (*e.g.,* direct blood to mucous membrane exposure). Universal precautions have been in place to prevent occupational exposure to BBF since 1983 (CDC 1996), yet the CDC considers that "risk following a blood exposure to the eye, nose, or mouth is unknown, but is believed to be very small" (CDC/NIOSH 2003). Therefore, there is a need to better understand the epidemiology and measure incidence, and to compare public health risk related to MSSIs to develop prevention strategies. The first research question asked how MSSIs compare to PCSIs in the period before, during, and after passage of the NSPA and subsequent promulgation into the OSHA Bloodborne Pathogens Standard in high compared to low risk hospital areas. Through this analysis, interpretations can be made about the potential impact of national policy on one type of blood and body fluid exposure compared to another.

It could be inferred from the available body of evidence that MSSIs occur less frequently in certain acute care (or inpatient) settings because there is little to no information about exposures in units that are not emergency, surgery, or dentistry (International Healthcare Worker Safety Center, 2009). "Lower exposure" units or hospital areas might include those such as radiography or physical therapy. In contrast, "high exposure" units or hospital areas are defined as those with an increased risk of BBF incidents due to the invasive nature of procedures (*e.g.,* operating room, obstetrics, or catheterization laboratory). To develop public health actions requires more evidence on the role of specific healthcare departments or areas in moderating how personal protective equipment is used and subsequent splash and splatter exposures are reported.

Certainly whether a healthcare worker works in a high risk unit (*e.g.,* units with more frequent splashes and splatters such as operating room, obstetrics, emergency department) moderates the rate of exposures (Jagger 1994, Purro 2001, Maritsa 2012). This study question looks at whether MSSI:PCSI ratios change over time across high and low hospital areas to determine if there are differences between the two BBF exposures.

Hypothesis 2: Healthcare workers who experience an MSSI wear personal protective equipment more frequently in high risk hospital areas than those in low risk hospital areas.

To better measure the occupational health impact related to overall use of PPE for reducing exposures to BBF, this study question examined potentially inter-related elements: are healthcare workers in high risk units more likely to wear PPE when a MSSI occurs and therefore less likely to have an exposure?

While traditional hazard abatement strategies (*e.g.,* elimination, substitution, engineering controls) in occupational safety and health focus on removing the hazard (*e.g.,* splash, splatter), in healthcare settings, where there is direct contact with patients, PPE use is often the most appropriate strategy. Hence, the impact of PPE use for splashes and splatters should be examined.

Hypothesis 3: Healthcare workers who experience an MSSI wear appropriate personal protective equipment more in high risk hospital areas than those in low risk hospital areas.

It has not been studied with this degree (number) of outcomes over time, whether healthcare workers are wearing the procedure- or risk-appropriate PPE when an incident occurs. This is an important qualifying factor because optimal exposure prevention hedges on the wearer having not only access to PPE in general, but whether they wear the appropriate PPE based on the anticipation of risk type (e.g. splashes or splatters to eyes, nose, mouth) outlined in their facility's Exposure Control Plan. Given that one would expect surgical masks to be worn the most frequently in hospital settings due to their use for both surgical procedures and for infection prevention/standard precautions from a patient safety point of view, it is unknown in the scientific literature if they are also preventing MSSIs that result in occupational exposures.

METHODS

Data Collection

The study populations (unit of study) were hospitals reporting their employees' occupational exposures to BBF. This includes PCSIs and MSSIs from 68 U.S. acute care hospitals that reported data using the EPINet™ surveillance system to the University of Virginia International Healthcare Worker Safety Center, over the time period of the study.

EPINet™ was developed by Janine Jagger, M.P.H., Ph.D., and colleagues in 1991 to provide standardized methods for recording and tracking percutaneous injuries and BBF contacts (IHWSC Website, 2010). The EPINet™ system consists of a *Needlestick and Sharp Object Injury Report* ("SOI") and a *Blood and Body Fluid Exposure Report* ("BBF"), and software programmed in Microsoft Access® for entering and analyzing the data from the forms. A post-exposure follow-up form is also available. Since its launch in 1992, more than 1,500 hospitals in the U.S. have acquired EPINet™ for use; it has also been adopted in other countries, including Canada, Italy, Spain, Japan and the United Kingdom. Hospitals contributing to the EPINet data system are self-selecting and not randomly assigned or selected. Contributions of exposure data are on a voluntary basis via an online data-sharing network managed by the IHWSC.

Contributing hospitals submit data annually by self-report for inclusion into the aggregate. Data are submitted via EPINet/Access downloadable forms available online (http://www.healthsystem.virginia.edu/internet/epinet/forms/epinet3.cfm). The majority of contributing facilities are located in the southern United States with others in Virginia, Pennsylvania, Ohio, Nebraska, California, Washington, and Oregon. A full list of contributing facilities is available on the IHWSC website (http://www.healthsystem.virginia.edu/internet/epinet/EPINetHospitalList.cfm). The numbers of contributing hospitals vary year to year (as high as 68 in 1995 and as low as 22 in 1999) and are described in detail in Appendix A

Exposures include incidents reported by contributing facilities via specific data entry screens to the IHWSC. Both the BBF and SOI reports are available in the Appendices B and C.

Dependent Variables

Hypothesis 1 states *"the ratio of reports of MSSIs to PCSIs was higher in high risk hospital areas than in low risk hospital areas"*. The dependent variable is the ratio between counts of MSSIs and PCSIs (MSSI / PCSI); labeled "MSSI:PCSI".

PCSIs were identified from the "*Needlestick & Sharp Object Injury*" report form. All PCSIs were captured no matter the sharp type (e.g. syringe, scalpel, IV needle, suture). MSSIs were identified from the "*Blood and Body Fluid Exposure Report*" (BBF) via Question 9 (Q9) of the report, which indicates exposed body part of healthcare worker. Specifically, it lists: intact skin, non-intact skin, eyes (conjunctiva), nose (mucosa), mouth (mucosa), and other. For this study, only the eyes, nose, and mouth were captured as those represent potential MSSIs.

Comparing only MSSI:PCSI ratios for all hospitals year to year (N=13) or period to period (N=3) allowed for only a descriptive analysis (Table 2.1), partly due to the absence of an appropriate denominator given that participating hospitals changed year to year. As such, the relationship between ratios and hospital area (high risk compared to low risk) over time was analyzed to determine if there was an effect on the ratios based on hospital area. This allowed for the more formal statistical testing described below.

Hospital areas, rather than entire hospitals, were selected as a means of comparison due to potential differences in selection and reporting criteria used across facilities contributing to the EPINet data sharing network, as well as a changing number of contributing facilities from year to year. Using ratios for the entire aggregate of all hospitals (as a whole organization) would not have allowed for a meaningful enough comparison. More importantly, hospital areas or departments may be more similar across hospitals than within them (Panlilio 1991, Tokars 1995, Jagger 1998, Puro 2001). Since all facilities that contribute to EPINet provide incident reports by hospital areas, comparing changes over time specific to area was felt to provide a more meaningful comparison. Therefore, we defined hospital units or departments (hereafter referred to as "hospital areas") as the key focus of analysis rather than whole hospitals.

In addition, because hospitals self-select into EPINet, there may be an influence similar to the healthy worker effect whereby hospitals that chose to submit their exposure reports may have tended to have fewer exposures. Hospitals volunteering their exposure report could feel they have nothing to hide compared to facilities that may have higher overall numbers of incidents and be more reluctant to share their data. This could underestimate the range of effects and is addressed further in the discussion section. The potential confounding effect can be corrected by looking at hospital areas within those contributing hospitals, rather than the hospital as a whole, which is why the comparison to determine differences between MSSIs and PCSIs was being performed across different hospital areas.

Hypothesis 2 states "*healthcare workers who experience an MSSI wear any personal protective equipment more frequently in high risk hospital areas than those in low risk hospital areas*". The dependent variable is "any PPE".

To assess whether employees reporting incidents were wearing any PPE, Question 11 (Q11) on the EPINet BBF Form was analyzed. EPINet captures information about the type of PPE worn by the employee at the time of the incident: barrier garments or PPE include selections for latex/vinyl gloves, goggles, eyeglasses, eyeglasses with side shields, face shield, surgical mask, surgical gown, plastic apron, lab coat/cloth, lab coat/other, and other. Specific to MSSIs, PPE includes eyeglasses, eyeglasses with side shield, goggles, face shield, or mask as already described. If any of these were worn during the MSSI exposure incident, they were identified as "any PPE". While eyeglasses on their own are not considered PPE, they were included in this analysis because they do serve as a barrier of protection for eye splashes.

Hypothesis 3 states "*healthcare workers who experience an MSSI wear appropriate personal protective equipment more in high risk hospital areas than in low risk hospital areas*". The dependent variable is "appropriate PPE" and was determined by combining the exposure type (e.g. eyes, nose, mouth) and whether the healthcare worker experiencing the MSSI indicated she/he was wearing procedure- and risk-appropriate PPE (*e.g.,* eyeglasses, eyeglasses with sideshields, goggles, masks, faceshields).

Based on the type of exposure indicated in Q9 and the response about type of PPE worn in Q11, appropriateness of PPE use was assessed for each reported incident (Table 1.0).

Table 1.0 Description of Personal Protective Equipment (PPE) Appropriateness Given Mucotaneous Splash and Splatter Incidents (MSSI) Type.

MSSI Body Part	PPE Reported Worn
Eyes	Eyeglasses, Side Shields, Goggles, Faceshield
Nose	Goggles, Faceshield, Surgical Mask
Mouth	Faceshield, Surgical Mask

Appropriate PPE use was defined by the following set of rules: PPE is appropriate for those incidents indicated for "eyes" (Eyes Yes = 1 "eyes", No = 0 all else); and the employee is wearing eyeglasses, eyeglasses with sideshields, faceshield, or goggles. If an incident is indicated for mouth (Yes = 1 "mouth", No = 0 all else), PPE use is appropriate if the employee is wearing faceshield or surgical mask. And finally, if the incident is indicated for nose (Yes = 1 “nose”, No=0 all else), similarly PPE use is appropriate if the employee is also wearing a faceshield or mask.

Independent Variables

For all three hypotheses, the independent variables were time period and hospital area (high risk and low risk). This analysis included a comparison by each of the following time periods: 1995-1999 (prior to the NSPA), 2000-2002 (reference period, passage of the NSPA and incorporation into OSHA’s BPS), and 2003-2007 (after enforcement of the OSHA BPS began); and an analysis in which all time periods were combined (1995-2007). Dummy variables were created for each time period: (0) for 1995-1999; (1) for 2000-2002 (reference period); and (2) for 2003-2007. Comparing across each study period allows for an analysis of whether there were changing ratios based on the passage of national policy and regulations and subsequent policy implications.

For hospital areas, the BBF Form was used to code the risk area independent variable, specifically Question 6 (Q6), “where” Access Column 6 to classify areas into:

High Risk Hospital Area (code 1) defined *a priori* in the published literature, and also stated in the “Public Health Significance” section (Jagger 1994, Purro 2001, Maritsa 2012) as follows:

1. High Risk “HiRisk”, “where” = 1 =any; Patient room (BBF Q6 “1”); Emergency (BBF Q6 “3”); Operating Room/Recovery (BBF Q6 “5”); Blood Bank (BBF Q6 “7”); Venipuncture (BBF Q6 “8”); Dialysis (BBF Q6 “9”); Labor/Delivery (BBF Q6 “16”); and,

Low Risk Hospital Area (code 0) was any of the remaining areas indicated on the reporting form and served as the referent group in the analysis:

2. Low Risk "LoRisk" Outside Patient Room (BBF Q6 "2"); Intensive/Critical Care (BBF Q6 "4"); Outpatient Clinic/Office (BBF Q6 "6"); Procedure Room (BBF Q6 "10"); Clinical Laboratories (BBF Q6 "11"); Autopsy/Pathology (BBF Q6 "12"); Service/Utility (BBF Q6 "13"); Home-care (BBF Q6 "17'); Other (BBF Q6 "14")

Statistical Analysis

For hypothesis 1, counts of MSSIs and PCSIs are described for each time period to establish size of study population or units of measure. Then ratios for each study period were calculated so that they could be compared for each time period. Then the change in ratios for each time period was analyzed. A preliminary analysis was conducted to look at the mean differences between MSSI:PCSI in the three time periods to identify if there was variability in means: a) 1995-1999; b) 2000-2002; and c) 2003-2007 by high and low risk hospital area. Dummy variables were used for both time period and risk area. For time period (0) represents 1995-1999, (1) represents 2000-2002, and (2) represents 2003-2007. Time period 1 is the reference period or also indicated as "NSPA". For risk area (0) represents low risk and (1) represents high risk. Risk area 0 is the reference period. It is important to determine if ratios are changing over time; then if they change over time dependent on hospital risk area; and then if the interaction between the two accounts for any change.

A one-tailed *t*-test was computed both for the overall study period and by comparing the means for each of the three study periods overall by hospital area. The formal test of hypothesis

1 analyzed the interaction between ratios over time and hospital area to determine if area had any influence as a function of time or time had any influence as a function of hospital area.

For the formal test of hypothesis 1, the following served as the linear equation.

$Y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 * x_2$, where

Y is the ratio of MSSI:PCSI counts.

α is the intercept.

β_1 is the beta coefficient or the slope parameter corresponding to the effect of time period with x_1 being the dummy variable for period (0) Pre-NSPA, (1) NSPA (reference period), (2) Post-NSPA,

β_2 is beta coefficient or the slope parameter corresponding to the effect of area with x_2 being the dummy variable for HiRisk vs. LoRisk areas (1 or 0),

$\beta_3 x_1 * x_2$ is the term for the interaction between time period and hospital area.

The primary test of the significance of the difference between means is a t-test of the coefficient □3; a p-value less than 0.05 was considered statistically significant. If the results were not significant, meaning ratios did not significantly vary by department over time, and then hypothesis 1 would be rejected.

For hypothesis 2, PCSIs were not considered. They were removed from the analysis moving forward. Eliminating PCSIs from the dataset reduces the study population (N) significantly and allows for a closer analysis of PPE use for MSSI reports to determine if there are differences accounted for by hospital area during the study period.

Counts and percentages of MSSIs by incident type (eyes, nose, mouth) were described for any PPE use by hospital area to re-establish study units of measure after the removal of the PCSIs from the data analysis. Hypothesis 1 compared MSSI to PCSI over time to determine if time could explain if there were differences for the MSSI:PCSI ratio by hospital areas, the interest for hypothesis 2 was whether hospital area influences the use of PPE during the study period. Analysis was conducted to determine if PPE use varies based on hospital risk area, again using the dummy variable (0) for low risk and (1) for high risk with (0) being the reference areas. If there were differences based on hospital area, it is important to establish if there was an interaction effect for hospital risk area and time period that may explain differences. This was conducted as a sensitivity analysis; if use of PPE varies by high and low risk departments, would that be because of an influence of time period. If PPE use did not vary over time by hospital areas, this could question the impact of the national policy given increased awareness on PPE use in hospitals.

Odds ratios (ORs) and corresponding 95% confidence intervals (CI) were calculated to measure the association between hospital area (independent variable) and any PPE (dependent variable) use overall. A p-value of 0.05 or less indicates statistical significance. The primary analysis was conducted using logistic regressions and calculating ORs for PPE use comparing high risk to low risk with low risk as the reference period. Then a sensitivity analysis was conducted using an interaction term for time to determine if time period was associated with any PPE use for high risk hospital areas compared to low risk.

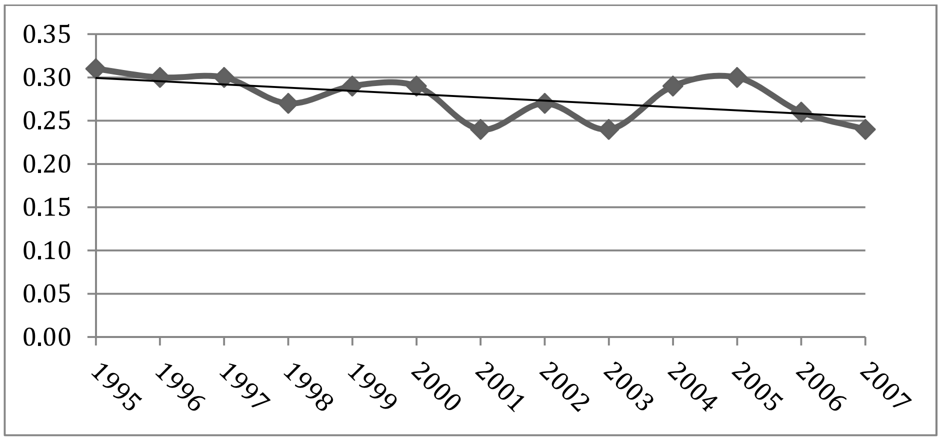
For hypothesis 3, again PCSIs were not considered. Similar to hypothesis 2, counts and percentages of appropriate PPE use based on the MSSI incident type were analyzed in order to describe the unit of study for this hypothesis. As detailed above in Table 1.0, if surgical masks were worn for a nose or mouth incident, it was considered “appropriate PPE”. “Appropriate PPE” was coded using (1) as a dummy variable and (0) when it was not appropriate, for example when a nose incident was reported and goggles were reported as being worn, it was coded with a (0).

Then, odds ratios with 95% confidence intervals were calculated for each type of appropriate PPE use for high risk compared to low risk hospital area for the entire study period to determine if there were different odds for the use of appropriate PPE use that could be associated with hospital risk area. A p-value of 0.05 or less indicates statistical significance. Interactions were then run to determine if any one type of appropriate PPE as having an observed effect on the others. Finally, to determine if time period had an interaction on appropriate PPE use for hospital area, a sensitivity analysis was conducted similar to hypothesis 2. Logistic regression with an interaction for hospital area and time period was conducted to determine whether this interaction was could explain an association of appropriate PPE use.

RESULTS

Overall, MSSI:PCSI ratios for all hospitals year to year (N=13) has a downward linear trend and the difference is statistically significant (p=0.04, CI -0.007, -0.0002).

Chart 2.0 Linear Trend of MSSI:PCSI for Each Study Year (1995-2007) for all Contributing Hospitals



With only 13 data points however, there are not enough units of measure to perform scientific analyses when comparing them year to year or period to period. The MSSI:PCSI ratios period to period (N=3) did not change significantly (p=0.90, 95% CI -0.03, 0.03). As such, the relationship between ratios and hospital area (high risk compared to low risk) over time was analyzed to determine if there was an effect on the ratios based on hospital area. This provides more points of measure.

The first study question asked whether MSSI:PCSI ratios were greater in high risk than in low risk hospital areas. The overall distribution of MSSIs, PCSIs and the MSSI:PCSI ratio by area and period is shown in Table 2.1.

Table 2.1 Counts of Mucotaneous Splash and Splatter Incidents (MSSIs) and Percutaneous Sharps Injuries (PCSIs) and MSSI:PCSI Ratios by Hospital Area and Time Period.

	Pre-NSPA (1995 – 1999)	NSPA (2000 – 2002)	Post-NSPA (2003 – 2007)	Overall Study Period (1995 – 2007)
MSSI incidents				
High Risk area	2,509	929	1,131	4,569 (13.9%)
Low Risk area	1,436	439	530	2,405 (7.3%)
Total	3,945	1,368	1,661	6,974 (21.2%)
PCSI incidents				
High Risk area	9,687	3,848	4,297	17,832 (54.3%)
Low Risk area	4,847	1,600	1,564	8,011 (24.5%)
Total	14,534	5,448	5,861	25,843 (78.8%)
				32,817 (100%)
MSSI:PCSI ratio				
High Risk area	0.26	0.24	0.26	0.26
Low Risk area	0.30	0.27	0.34	0.30
Total	0.27	0.25	0.28	0.27

To describe incidents over each time period, the majority of incidents in all study time periods were PCSIs (78.8%) compared to MSSIs (21.2%) with the largest number/percentage of PCSIs (44.3%) being reported Pre-NSPA. The ratios did change over time with a dip during the reference period (NSPA 2000-2002), but the differences were not statistically significant ($p=0.90$).

To examine differences in MSSI:PCSI ratios between high risk and low risk areas, a one-tailed paired *t*-test was computed both for the overall study period and by comparing the means for each of the three time periods (Table 2.2).

Table 2.2 Ratio of MSSI:PCSI for High Risk and Low Risk Hospital Areas in 3 Study Periods

	Mean Number of Hospitals (Range)	Mean Ratio	(95% CI)[a]	P-value[b] High > Low
Overall	45 (22,68)			0.81
High risk area		0.26		
Low risk area		0.32		
Pre-NSPA	45 (22,68)			0.99
High risk area		0.26	(0.24, 0.27)	
Low risk area		0.30	(0.28, 0.32)	
NSPA	42 (26,58)			0.99
High risk area		0.25	(0.23, 0.27)	
Low risk area		0.29	(0.26, 0.31)	
Post-NSPA	41 (29,53)			1.00
High risk area		0.26	(0.24, 0.28)	
Low risk area		0.35	(0.31, 0.39)	

a. 95%CI = 95% confidence interval.
b. P-value from paired t-test for high risk with a mean ratio higher than low risk areas.

Though the numbers of contributing hospitals varied year to year, the mean number was similar (range from 41-45) and the core hospitals were the same. Therefore number of hospitals was not expected to have an influence on overall ratios for each study period. Contrary to our hypothesis, neither overall nor by study period the MSSI:PCSI ratio was higher in high risk areas than in lower risk areas. In fact, the MSSI:PCSI ratio our results contradicted our hypothesis since the ratio was higher ($p<0.05$) in lower areas than in high risk hospitals areas.

As a formal test of the hypothesis, and as described above, several linear regression models were run with interactions. The results from the interactions, the formal tests of this hypothesis, are presented in Table 2.3. Because the preliminary analysis indicates that time period is not a predictor of changing ratios, the subsequent analyses examine if an interaction between the variables does. The following are analyzed; (1) difference between overall MSSI:PCSI ratio by hospital area with low risk area as the reference indicated in Table 2.3 below, (2) difference between overall MSSI:PCSI ratio by period using NSPA period as the reference, (3) difference between overall MSSI:PCSI ratio stratified by time period and by hospital area, and, (4) difference between MSSI:PCSI ratio by the interaction of area, time period, and area x time period and is indicated by “Interaction”.

Table 2.3 Linear Regression Models for MSSI:PCSI with Interaction Effect for Time Period and Hospital Area

	Intercept	β (95% CI)	F-statistic	p-value	R^2
Crude [a]					
Area	-0.03		F(1,4)=5.49	0.08	0.58
Low risk		Ref.			
High risk		-0.05 (-0.11, 0.01)			
Period	-0.02		F(1,118)=11.00	0.001	0.09
Pre-NSPA		-0.05 (-0.11, 0.00)			
NSPA		Ref.			
Post-NSPA		-0.05 (-0.11, 0.00)			
Adjusted [b]	-0.01		F(2,32814)= 4.44	<0.001	0.00
Area					
Low risk		Ref.			
High risk		0.00 (0.01, 0.01)			
Period					
Pre-NSPA		0.12 (0.01,0.01)			
NSPA		Ref.			
Post-NSPA		0.01(0.01,0.12)			
Interaction [c]	-0.02		F(3,32813)= 13.34	<0.001	0.07
Low Risk & Pre-NSPA		0.01 (0.00, 0.03)			
Low Risk & NSPA		Ref.			
Low Risk & Post-NSPA		0.02 (0.02, 0.05)			
High Risk & Pre-NSPA		0.03 (0.02, 0.05)			
High Risk & NSPA		0.02 (0.00, 0.04)			
High Risk & Post-NSPA		0.01 (0.00, 0.003)			

a. Separate models for each variable.
b. Both variables included in the same model.
c. Combination of area and time period

The interaction was not statistically significant and the hypothesis that the ratios of MSSI:PCSI differ over time was rejected. Incorporating the interaction did not show any statistically significant ($p>0.05$) results when comparing each time period.

The negative coefficients for the crude analysis are consistent with the t-test results. MSSI:PCSI ratios are not higher for high risk hospital areas. In the analysis where the ratio is stratified by time period there seems to be no differential effects of area risk by period, nor an interaction term between period and area showed such an effect.

For the second study question, to describe the data set or units of measure with the removal of PCSIs from the analysis; 25,843 data points were removed that were analyzed in hypothesis 1 (refer to Table 2.1). Total counts of MSSIs were calculated by type: eyes, nose, and/or mouth where any PPE was worn. This eliminated 1,936 MSSIs from the study period that were incidents where no PPE use was reported (refer to Table 2.1). Implications of this will be further explored in the discussion section. Table 2.4 shows the frequency of various types of MSSIs and their distribution across high and low risk hospital areas for the entire study period.

Table 2.4 The Frequency of Eyes, Nose, Mouth MSSI by Hospital Area during the Study Period 1995-2007.

	Low Risk	High Risk	Total
Eyes	1,316	2,680	3,996 (79%)
Nose	113	197	310 (6%)
Mouth	266	466	732 (15%)
Total	1,695 (34%)	3,343 (66%)	5,038 (100%)

Sixty-six percent of MSSI incidents with use of PPE occurred in high risk hospital areas. Eye incidents (79%) made up the majority of exposure type across all study hospitals. There were 152 incidents where the eyes, nose, and mouth were all identified for the incident of which 63% (96) were in high risk hospital areas.

Next, to describe the frequency of use of any PPE, counts were calculated by PPE type as a means to describe the data set for hypothesis 2. Table 2.5 shows the frequency of any PPE use across hospital areas.

Table 2.5 The Frequency of PPE Use by Hospital Area during the Study Period 1995-2007

	Low Risk	High Risk	Total
Eyeglasses	278	593	871 (39%)
Side Shield	6	30	36 (2%)
Goggles	65	163	228 (10%)
Faceshield	46	190	236 (10%)
Mask	178	707	885 (39%)
Total	573 (25%)	1,683 (75%)	2,256 (100%)

The majority of PPE use occurred in high risk hospital areas (75%). The most frequently worn type of PPE in high risk hospital areas was a mask (42%), likely due to the fact that the majority of incidents are reported in surgical settings/operating rooms. There is a difference between MSSIs with any PPE use reported compared to PPE use reported because multiple incidents involved multiple mucus membranes and multiple PPE combinations. For example, an MSSI to the eyes, nose, and mouth can be counted as 3 incidents, but the use of a faceshield only 1. This will be explored further in the discussion.

For the third hypothesis, appropriateness of PPE use was analyzed. Much like hypothesis 2, first frequencies of appropriate PPE use were described to establish the data points that will be used in the preliminary and formal tests. Table 2.6 shows the frequency of appropriate PPE use by hospital area and type of incident.

Table 2.6 Frequency of Appropriate PPE Use by Hospital Area for the Study Period 1995-2007.

		Eyeglasses	Side Shield	Goggles	Faceshield	Mask	ALL
Eyes:	Low Risk	149	5	27	28		209 (22%)
	High Risk	360	23	101	116	N/A	579 (65%)
Nose:	Low Risk				5	9	14 (2%)
	High Risk	N/A	N/A	N/A	9	15	24 (3%)
Mouth:	Low Risk				4	6	10 (2%)
	High Risk	N/A	N/A	N/A	12	18	30 (3%)
							887 (100%)

The majority of appropriate PPE being worn were eyeglasses; whether eyeglasses are actually PPE will be discussed later. Eyeglasses were indicated more frequently in high risk hospital areas (65%) rather than low risk (22%). Faceshields were worn more frequently in high risk hospital areas (range, 64% to 81%) for all exposure types as they serve as PPE for all exposure types.

There were 152 incidents simultaneously involving the eyes, nose, and mouth; of these, only 3 were wearing faceshields. Because these numbers were so low, they were not included in the overall analysis. Another appropriate selection other than faceshield would have been some form of eye PPE combined with a mask, but no employees noted this combination on the BBF report form.

In a preliminary analysis of MSSI events, odds ratios (ORs) were calculated to measure the association between "any PPE" use for MSSI events high and low risk hospital areas. The same analysis was performed between "appropriate PPE" and hospital area.

Table 2.7 shows the odds of wearing any PPE for MSSIs and then the odds of wearing the appropriate PPE given the type of MSSI incident (eyes, nose, mouth) occurring in a high risk hospital area, with low risk hospital area as the referent group.

Table 2.7 Odds Ratios (OR) of MSSI by type and *Any* PPE for High and Low* Risk Hospital Area.

	OR	(95% CI)
Any PPE	1.58	(1.35, 1.72)
Eyes	1.44	(1.28, 1.62)
Nose	1.68	(1.30, 2.18)
Mouth	1.68	(1.40, 2.01)

*Low Risk Hospital Area is the Referent Group

These results suggest it was more likely that any PPE was worn in high risk hospital areas than in low risk hospital areas across all three MSSI types, and are statistically significant. This supports hypothesis 2 that PPE is being worn more frequently in high risk hospital areas compared to low risk hospital areas.

Table 2.8 shows the odds of the appropriateness of PPE use, given the type of MSSI incident.

Table 2.8 Odds Ratio (OR) of MSSI by Type and *Appropriate* PPE for High and Low Risk* Hospital Area

	OR	(95% CI)
Appropriate PPE	1.58	(1.40, 1.78)
Eyes	1.41	(1.18, 1.68)
Nose	0.98	(0.47, 2.14)
Mouth	1.71	(0.80, 4.00)

* Low Risk Hospital Area is the Referent Group

Unlike the odds ratios for any type of PPE use in high versus low risk hospital areas, the odds ratios for *appropriate* type of PPE yielded different results. While it was more likely that appropriate PPE will be worn for eye and mouth incidents in a high risk hospital area, this was not apparent for nose incidents.

Logistic regression was performed for each type of PPE for high and low risk hospital areas. Table 2.9 shows the odds ratios from those regressions.

Table 2.9 Logistic Regression of Each PPE Type by Hospital Area* for the Study Period 1995-2007

	OR	95% CI
Any PPE	1.53	(1.35, 1.72)
Eyeglasses	1.03	(0.88, 1.20)
Sideshield	1.97	(1.78, 2.57)
Goggles	0.95	(0.71, 1.29)
Faceshield	1.51	(1.78, 2.57)
Mask	2.14	(1.63, 1.82)

*Low Risk Hospital Area is the referent group

The results suggest it was more likely that any PPE is worn in high risk compared to low risk with one exception (goggles). The most frequently worn PPE in high risk hospital areas are eyeglasses with sideshields and masks (OR = 1.97, OR = 2.14, respectively).

Next, as a sensitivity analysis, a logistic regression was run for appropriate PPE use for each MSSI incident type in high and low risk hospital areas (Table 2.10).

Table 2.10 Logistic Regression for Appropriate PPE by Hospital Area* for the Study Period 1995-2007

	OR	95% CI
Appropriate PPE	1.58	(1,40, 1.78)
Eyes	1.37	(1.20, 1.57)
Nose	2.26	(1.90, 2.67)
Mouth	2.26	(1.90, 2.67)

*Low Risk Hospital Area is the Referent Period

It is more likely that healthcare workers are wearing PPE appropriate for nose and mouth MSSIs in high risk hospital areas (OR = 2.26, CI 1.90, 2.67) as compared to low risk areas. As indicated above, eyeglasses are most frequently worn for eye MSSIs in both high and low risk hospital areas. All ORs were statistically significant.

Next, logistic regression with the interaction of time period was considered. Table 2.11 is the logistic regression for any PPE and appropriate PPE by hospital area (reference period is NSPA) for each study period as an interaction term.

Table 2.11 Logistic Regression for the Relationship of Hospital Area* for Any PPE and Appropriate PPE

		OR	(95% CI)
Any PPE			
	Pre-NSPA	0.95	(0.82, 1.10)
	NSPA	Ref	
	Post-NSPA	1.00	(0.84, 1.18)
Appropriate PPE			
Eyes	Pre-NSPA	0.90	(0.76, 1.05)
	NSPA	Ref	
	Post-NSPA	0.96	(0.80, 1.16)
Nose	Pre-NSPA	0.98	(0.82, 1.19)
	NSPA	Ref	
	Post-NSPA	1.19	(0.97, 1.47)
Mouth	Pre-NSPA	0.98	(0.82, 1.20)
	NSPA	Ref	
	Post-NSPA	1.20	(0.97, 1.48)

* Low Risk Hospital Area is the Referent Area and NSPA is the Referent Time Period

It appears that, during the Pre- and Post-NSPA periods, the odds of employees wearing any PPE changes only slightly compared to the NSPA reference period. No change was statistically significant. When calculating ORs for the NSPA only, odds were higher that appropriate PPE was being worn (OR = 1.36, CI 1.19, 1.56) this was the only odds ratio that was statistically significant. While the ORs during the NSPA are statistically significant, the odds in the other time periods are not.

DISCUSSION

This study measured more than 32,000 BBF exposure incidents (MSSIs and PCSIs) from 68 U.S. hospitals reporting into EPINet from 1995-2007. Three hypotheses were tested. First, results indicated for hypothesis 1 that ratios of counts between MSSI and PCSI in high and low hospital risk areas had not changed over time, despite new lawmaking and subsequent regulatory action. The counts and ratios of MSSIs to PCSIs varied only slightly over three study periods, with a slight dip for the ratio during the reference period (0.27, 0.25, 0.28 respectively); none of these was statistically significant.

Since MSSIs to PCSIs showed no difference over time for high and low risk hospital areas, we then tested for differences in any PPE use by hospital area. Eye exposure incidents were the most common in both high and low risk areas, but wearing PPE was more likely in high risk areas.

Finally, the results indicate that PPE is used more appropriately in high risk hospital areas. Eye protection, as a PPE category, was worn more often in high risk areas, but masks were the type most frequently used. During the period of development and implementation of the policy it was more likely that PPE would be worn, and that this PPE would be used appropriately. The odds of wearing nose and mouth appropriate PPE was higher than for the eyes.

This study yielded some surprising results. First, ratios of MSSIs to PCSIs did not change over time despite passage of a national policy. It was expected that since policy focused on needlesticks that when comparing them to another type of exposure – MSSI – that there would be a change across time periods. Second, it was more likely that healthcare workers reporting into EPINet wore PPE more in high risk hospital areas, there was higher odds for eye and mouth appropriate PPE and not for nose (OR = 0.98, CI 0.47, 2.14); when analyzed with time as an interaction, however, it was more likely that PPE for the nose and mouth were worn. This variation may be explained by the selection of a surgical mask versus faceshield for high risk areas like surgery, and the potential implications of not wearing masks appropriately so that they cover the entire nasal mucosa. Bentley and team also describe the impact of failures of PPE to prevent exposures due to PPE being inappropriately worn or PPE product failures (Bentley 1996). Discussed below in the limitations section, is the exploration of the shortcomings of the type of data that is reported in the aggregate, meaning it is uncertain if HCWs wearing a mask with a visor would report that as a faceshield or as a mask and goggles. Third, use of both any and appropriate PPE appeared more likely during the period of passage and implementation of the national policy, for high risk hospital areas.

Ratios

When comparing exposure incidents by hospital area, MSSI:PCSI ratios were not affected by hospital area, and were actually significantly higher in *low* risk hospital areas (*e.g.,* inside and outside of patient rooms, procedure rooms like radiology). Subsequently, however, interactions between both study period and hospital area resulted in no difference. Because MSSI:PCSI ratios are higher in low risk areas indicates that more MSSIs compared to PCSIs are occurring and, as such, splashes and splatters may be a more prevalent exposure type than are needlesticks and more attention needs to be paid to the availability and appropriate use of PPE to prevent these incidents. Conversely, needlesticks may occur less often in low risk hospital areas because the majority of sharps injuries occur in high risk settings like surgical or catheterization. Both of these scenarios would increase the MSSI:PCSI ratio.

With little change of the ratios across time period, it is clear that time period is not a significant indicator of the ratio between MSSI and PCSI and that there may be policy implications when determining whether the NSPA and subsequent uptake in the OSHA BPS resulted in changes of PCSIs compared to MSSIs.

It was anticipated that, because of a greater focus on PCSIs during the reference period, PCSIs would decline compared to MSSIs in those hospital areas. It was also anticipated that there would be greater reductions in PCSI incidents with the required use of safety needles and similar safety devices; therefore, as PCSIs declined, the MSSI:PCSI ratio would increase. After performing the data analyses however, there was no statistically significant difference between MSSIs and PCSIs in any time period, despite this expectation.

PPE Use

While traditional hazard abatement strategies (*e.g.,* elimination, substitution, engineering controls) in occupational safety and health focus on removing the hazard (*e.g.,* splash, splatter), in healthcare settings, where there is direct contact with patients, workers often use PPE. Currently, there are limited commercially available engineering controls for blood exposures. When there are, it would be important to reassess.

By comparing incidents where PPE was used appropriately in, we were able to determine if PPE matches exposure incident type. Eye exposures were the most frequent. And while eyeglasses are not traditionally considered a form of PPE for eyes, they do serve as a barrier for splashes to the eyes. From this study, it cannot be measured if they were being worn as PPE or simply for vision correction. There was a greater odds (OR=1.41) that they were worn in high risk compared to low risk hospital areas. This is interesting because, if eyeglasses were worn for vision correction, one would not expect them to be worn more frequently in one type of hospital department or area over another, but this was the case and it was statistically significant (CI = 1.40, 1.78, $p < 0.00$). Akduman et al (1999) identified that operating room personnel wear glasses 24% of the time as PPE. While operating rooms were not called out specifically, this study confirms that in this study population, eyeglasses are worn as a barrier precaution and that they are worn more in high risk areas (26%) compared to low risk (12%) when an MSSI was reported.

In this sample of incidents, faceshields were worn more often in high risk areas (64%). This may be because they are being worn as procedure-appropriate PPE in surgical settings that make up the majority of incident reports. Curiously, faceshields are worn more frequently with eye exposures rather than those reported to the nose or mouth. Given the volume and pressure of blood exposures in surgical settings, it is surprising that eye exposures (80%) outweigh nose (6%) or mouth (15%). Perhaps it is during surgical procedures that surgical staff are wearing masks and, as such, preventing nose and mouth exposures. Clearly more careful attention should be paid to wearing eye protection in addition to nose and mouth protection (i.e. surgical masks) in high risk settings.

Strengths

To our knowledge, this is the largest data set of its kind over the largest period of time ever studied. In analyzing, describing, and quantifying more than 32,000

BBF exposures from nearly 70 U.S. hospitals, strengths of this study include its size and likely generalizability, which allows it to inform regional and national policy discussions.

Since EPINet is the largest database of its kind and no other national or state organization collects such a breadth of data, neither nationally nor worldwide, the ability to use this dataset was a notable strength in itself. The analyses of EPINet in the published literature has been a service to public health to be able to monitor and measure incidents over time.

The use of “MSSI” as defined as a dependent variable in this study is one of its strengths. MSSIs are more specific of a measure (incident to eyes, nose, mouth) than what is described in the published literature. Current peer-reviewed publications use reports of “blood or body fluid” exposures and tend to count or measure needlesticks specifically, and then use a general category of “other” to address all non-percutaneous injuries (Alamgir 2008, Mbaisi 2013). “Other” categories typically include all blood and body fluid splashes and splatters to not just those to the mucus membranes. As such, using a more specific exposure type – MSSI – this analysis may increase the reliability with which “risk” can be compared where potential pathogens gain entry into mucus membranes (MSSIs).

Locally, hospitals will be able to use similar scientific models derived in this study to assess and compare exposure incidents in their own facilities over time as a means to inform occupational risks, hazards, PPE, and incidents of BBF exposures. This study confirms what Gershon et al (1995) described in their study that measured exposures that were occurring because of marginal or poor PPE compliance. It also details exposure incident types (MSSIs) that occur because of lack of PPE use beyond what Jagger and her team described in 1998 because it is specific to type of MSSI, and type and appropriateness of PPE. It also more accurately measures the degree of appropriate PPE use than other papers published recently, as these studies look at all PPE rather than incident-appropriate PPE (Matthews 2008, Sacchi 2007, Afridi 2013).

Nationally, policy makers, regulators, and researchers may be able to use similar types of analyses to assess the impact of new or existing standards or policies. By comparing one type of exposure to another (MSSI to PCSI), it is possible to see whether one changes as a function of targeted action/intervention.

Limitations

Factors related to the facility and hospital area may confound the association of effect of incident report counts. These may include what is unknown and thus not analyzed in this study including type and size of contributing hospital, geographical location, setting (rural, suburban, urban), and number of years the facility has been an EPINet contributor. Since the hospitals contributing to the aggregate EPINet were assured confidentiality, it was not possible to analyze hospitals by type, size, and specialty. It is therefore not possible to analyze rates by hospital over time. A study could be conducted that may yield valuable results if incidents could be linked to the hospitals that are reporting them, if confidentiality is a key driving factor for lack of disclosure, a number can be assigned and hospital name can be blind to the researcher.

Demographic information related to the employees reporting incidents is not available; as such, we could not analyze for confounding or modifying effects related to an employee's years of clinical work experience, degree of training, gender, age, previous exposure, continuous shift hours worked, and anticipation of risk which may be potential covariates. Incident reports also are dependent on how employees and record keepers voluntarily report incidents and how they identify the hospital areas in which they work. While parameters are established to define hospital areas on the EPINet forms, there are no means by which to measure consistency and compliance of appropriate hospital area reporting. For example, a healthcare worker that works in a specialty area like ICU could indicate when an exposure occurred that they were in a patient room if the ICU room is single occupancy. This leaves room for individual reporting bias.

Exposure reporting is voluntary, both from an employee to employer perspective and from a facility to EPINet perspective. Because of this, the exposures and risks of exposures may have been underestimated and subject to recall and reporting bias. Employees may experience an exposure incident and not fill out a report form for multiple reasons, including lack of time and lack of concern or knowledge of a report form. As well, if employees do fill out a report form, they may wait until they have time to fill it out and incorrectly remember the details of the exposure. Employers may not include all forms into their report for multiple reasons including failure to collect all forms, failure to standardize reporting across all departments in hospital, or failure to routinely report each year.

One of the limiting factors associated with determining whether employees were wearing appropriate PPE is that there is not an opportunity for employees who did have an MSSI to indicate that they were wearing "no" PPE or "none" on the EPINet form. And since written entries were not analyzed for this study, it is not certain what an employee would identify on the form if they were wearing no PPE. This becomes problematic because those incidents that did occur where employees were wearing no PPE may not have been captured appropriately and may be underestimated. Likewise, this study cannot identify, as Bentley et al (1996) did, that incidents may occur while an employee is wearing PPE, but there is a failure of that PPE to prevent an exposure (e.g. when goggles slip or faceshields are loose).

Another limitation is that the frequencies of types of MSSIs (6,974) above do not translate into the overall cumulative number of mucotaneous exposures reported in EPINet because some incidents were reported where MSSIs hit only the PPE (incident) and not the mucus membrane itself (exposure). In other words, an employee could have reported that while there was not a splash to their eye, there was a splash to their goggles. These were included however, because PPE incidents represent near hits that are important to capture. Conversely, this dataset does not allow for the analysis of the underpinnings of what may be occurring in the contributing hospital, meaning that from hospital to hospital there may be differing policies or practices related to reporting of splashes or splatters to PPE only (or near hits, exposures that could have happened but did not because PPE was being worn). It is likely that if an MSSI occurred to the surface of the PPE only, that it would not be reported and thus unknown. This is both an important limiting factor of this research, as well as a topic that needs further study. Do all hospitals report MSSIs the same? And further, do all employees report MSSIs the same? Does this appropriately measure MSSIs as many employees may not report a splash to their PPE?

Despite the limitations, this research provides a unique opportunity to measure both the influence of policy on occupational exposure to blood and body fluids, as well as the use of PPE for MSSIs. It expands the body of scientific evidence that builds a case for placing national attention on exposures that can cause occupationally-associated infections (OAIs).

Recommendations for Further Study

OSHA Recordability

Whether or not an incident was OSHA recordable could be valuable information to assess severity and risk. Both the BBF and SOI reports indicate whether the exposure incident was “OSHA reportable”. While this was not researched in this study, it could be researched and described further in another analysis. A percentage and odds ratios could be established to determine of the exposures that are occurring, which ones are OSHA recordable (requiring more that first aid follow-up). If they are OSHA recordable, it would imply that PPE is being worn, but it is not appropriate, as PPE is not preventing splashes and splatters into eyes, nose, or mouth.

Denominators

There are great differences among injury epidemiologists and occupational safety and health professionals about the most appropriate denominator for occupational incidents involving blood and body fluids. Literature from primary investigators at the IHWSC use “occupied-bed days”, others use straight percentages (exposures/all employees), (exposures/all procedures), or time (exposures/year).

In this dataset, full-time equivalents (FTEs) are not known. While not knowing FTEs may be a limitation - given this analysis is contributing to a largely under-published body of evidence - odds ratios may be sufficient to describe exposures at this juncture. A scientific analysis should be conducted of incident data that is identifiable by (linked to) hospital, so that rates over time can be measured and compared. While aggregate data can paint a picture, it cannot do so in a way that is meaningful for analysis and change at a geographic or hospital level.

Future applications of this research could include the following:

- Changing and/or improving PPE protection guidance, as well as appropriate PPE use overall, with support from Federal agencies (OSHA, CDC, NIOSH)
- Changing and/or improving PPE protocols and institutional practices and recommendations for mucotaneous exposures to blood and body fluids
- Changing and/or improving PPE wearing practices by clinical staff when performing procedures with potential exposure in both high and low risk hospital areas
- Research and development of innovative PPE products and services offered by makers, manufacturers, and distributors

- Decreasing occupational mucotaneous exposures to blood and body fluids in hospitals and potentially other healthcare settings, therefore decreasing occupational-associated infections (OAIs)

In summary, this study fills some obvious gaps in healthcare worker safety and health research. It provides insights into the lack of effect that national policy had on reducing both MSSIs and PCSIs. Unlike CDC's assessment that risk of blood exposure is "very small", this research illustrates that not only are blood and body fluid exposures occurring frequently, but that high risk occupational incidents like MSSIs are occurring without the use of PPE. Mucotaneous exposures will continue to occur if close attention is not paid to the availability and appropriate use of PPE, especially in often overlooked low risk hospital areas. While BBF exposure does not directly translate to occupationally-associated infections (OAIs) and while national policy may not be the sole answer, the risk of exposure is too great for the public health community to ignore.

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APPENDIX A: CONTRIBUTING HOSPITALS

U.S. EPINet Sharps Injury and Blood and Body Fluid Exposure Surveillance Research Group: Participating Healthcare Facilities, 1995-present

Year	# Teaching Facilities	# Non-Teaching Facilities	TOTAL (Difference from Reference Period)
1995	27	41	**68 (+10)**
1996	26	39	**65 (+7)**
1997	19	36	**55 (-3)**
1998	20	32	**52 (-6)**
1999	13	9	**22 (-36)**
2000	11	15	**26 (-32)**
2001	13	45	**58**
2002	11	42	**53 (-5)**
2003	12	41	**53 (-5)**
2004	9	35	**44 (-14)**
2005	10	26	**36 (-22)**
2006	9	24	**33 (-25)**
2007	9	20	**29 (-29)**
			Range: 68, 22 **Variance: (+10, -32)**

APPENDIX B: BBF EXPOSURE REPORT

Blood and Body Fluid Exposure Report

EPINet™
FOR MICROSOFT•ACCESS
EXPOSURE PREVENTION INFORMATION NETWORK

V1.2/US 3/2001

Last Name: ________________________ First Name: ____________________

Exposure ID: *(for office use only)* B________ Facility ID: *(for office use only)* __________

1) Date of Exposure: ☐☐ ☐☐ ☐☐☐ **2) Time of Exposure:** ☐☐ ☐☐

3) Department where Incident Occurred: _____________________

4) Home Department: ________________________

6) Where Did the Exposure Occur? (check one box only)

- ☐ 1 Patient Room
- ☐ 2 Outside Patient Room *(hallway, nurses station, etc.)*
- ☐ 3 Emergency Department
- ☐ 4 Intensive/Critical Care unit: specify type: ______________
- ☐ 5 Operating Room/Recovery
- ☐ 6 Outpatient Clinic/Office
- ☐ 7 Blood Bank
- ☐ 8 Venipuncture Center
- ☐ 9 Dialysis Facility *(hemodialysis and peritoneal dialysis)*
- ☐ 10 Procedure Room *(x-ray, EKG,etc)*
- ☐ 11 Clinical Laboratories
- ☐ 12 Autopsy/Pathology
- ☐ 13 Service/Utility *(laundry,central supply,loading dock,etc)*
- ☐ 16 Labor and Delivery Room
- ☐ 17 Home-care
- ☐ 14 Other, describe: ________________

9) Was the Exposed Part: (check all that apply)

- ☐ Intact Skin
- ☐ Non-Intact Skin
- ☐ Eyes (*conjunctiva*)
- ☐ Nose (*mucosa*)
- ☐ Mouth (*mucosa*)
- ☐ Other, Describe: ___________________

11) Which Barrier Garments were Worn at the Time of Exposure: (check all that apply)

- ☐ Single Pair Latex/Vinyl Gloves
- ☐ Double pair Latex/Vinyl Gloves
- ☐ Goggles
- ☐ Eyeglasses *(not a protective item)*
- ☐ Eyeglasses with Side shields
- ☐ Face shield
- ☐ Surgical Mask
- ☐ Surgical Gown
- ☐ Plastic Apron
- ☐ Lab Coat, Cloth *(not a protective garment)*
- ☐ Lab Coat, Other
- ☐ Other, Describe: ____________________

APPENDIX C: SOI REPORT

Needlestick & Sharp Object Injury Report

EPINet™

FOR MICROSOFT® ACCESS

EXPOSURE PREVENTION INFORMATION NETWORK

V1.2/US 3/2001

Last Name: ________________________ First Name: ____________________

Injury ID: *(for office use only)* **S**_____ Facility ID: *(for office use only)* _____ **Completed By:** _____

1) Date of Injury: ☐☐ ☐☐ ☐☐☐ **2) Time of Injury:** ☐☐ ☐☐

3) Department where Incident Occurred: ______________________

4) Home Department: ________________________

6) Where Did the Injury Occur? (check one box only)

- ☐ 1 Patient Room
- ☐ 2 Outside Patient Room *(hallway, nurses station, etc.)*
- ☐ 3 Emergency Department
- ☐ 4 Intensive/Critical Care unit: specify type: ______________
- ☐ 5 Operating Room/Recovery
- ☐ 6 Outpatient Clinic/Office
- ☐ 7 Blood Bank
- ☐ 8 Venipuncture Center
- ☐ 9 Dialysis Facility *(hemodialysis and peritoneal dialysis)*
- ☐ 10 Procedure Room *(x-ray, EKG,etc)*
- ☐ 11 Clinical Laboratories
- ☐ 12 Autopsy/Pathology
- ☐ 13 Service/Utility *(laundry,central supply,loading dock,etc)*
- ☐ 16 Labor and Delivery Room
- ☐ 17 Home-care
- ☐ 14 Other, describe: _________________

9) The Sharp Item was: (check one box only)

- ☐ 1 Contaminated (known exposure to patient or contaminated equipment)
- ☐ 2 Uncontaminated (no known exposure to patient or contaminated equipment)
- ☐ 3 Unknown

was there blood on the device? ☐ 1 Yes ☐ 2 No