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Occupational Sharps Injuries in Medical Trainees at the University of South Florida: A Follow-up Study

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by

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Abstract

Medical trainees (medical students and resident physicians) are at high risk of sharps injury (needlestick injury). High rates of sharps injury in this population and the risk incurred by exposure to bloodborne pathogens pose a threat both to medical trainees who are at risk for bloodborne pathogen exposure and to training institutions for legal and financial reasons. This study examines the prevalence of sharps injuries in medical trainees at the University of South Florida and compared it to data on sharps injuries in US medical trainees. Data from the present study was compared to previously collected USF medical trainee sharps injury data. Results from this study demonstrated that residents had higher rates of sharps injury than medical students. A prior USF study of similar data from academic years 2002-2008 had similar findings. This study also demonstrated a peak in sharps injury rate in first year residents, similar to the prior USF study. Resident rates remained highest in Surgery and lowest for Psychiatry and Pediatrics. This information can be used to focus hazard analysis and risk reduction efforts at USF Health. This data can also be combined with the known efficacy of simulated training experience should encourage increased use of USF's center for advanced medical simulation (CAMLS) to increased procedural experience in medical students and junior residents and decrease their exposure to bloodborne pathogens by increasing and procedural safety and experience.

Chapter 1: Introduction

Healthcare workers are frequently exposed to potentially infectious blood and body fluids (BBF) in the course and scope of patient care. With over 385,000 annual needlestick injuries in United States (US) hospital-based healthcare workers (HCWs), needlesticks (sharps injuries or percutaneous injuries) pose a significant occupational hazard.[1,2] Sharps injuries are defined by injury causing a break, puncture, cut or scrape of the skin, whereas mucocutaneous (splash) injuries indicate an exposure to potentially infectious blood or bodily fluid to an area of intact skin or mucous membrane, such as the eyes or mouth.[1] Exposure to bloodborne pathogens (BBPs) and the potential for HCW seroconversion and chronic infection by Hepatitis B (Hep B), Hepatitis C (Hep C) or Human Immunodeficiency Virus (HIV) remain primary concerns for sequelae of needlestick injury.[1] These top 3 BBPs are not the only concern with over 20 other known potentially infectious bloodborne agents including: syphilis, malaria, dengue, Ebola, Zika virus, babesiosis, brucellosis, leptospirosis, Creutzfelt-Jacob disease, and Colorado tick fever.[3,4] Because of this risk, the Occupational Safety and Health Administration (OSHA) passed the Needlestick Safety and Prevention Act (NSPA) of 2000 updating the BBP standard of 1991 and requiring employers by force of law to protect employees from BBP exposure through implementation of safety engineered sharps devices (SESDs) in workplaces.[5]

Less than 10% of HIV infections in HCWs are occupationally acquired. 88% of occupationally-acquired HIV seroconversions in HCWs are due to sharps injuries.[6] The rate of HIV transmission due to a single needlestick is estimated to be 0.3%. There are 58 documented cases and 150 possible cases of occupationally-acquired HIV in HCW between 1985 and 2015.[7] Of these 58 occupationally acquired cases, 8 HCWs became HIV positive despite receiving post-exposure prophylaxis.[6] An estimated 37% of chronic Hep B infections in HCWs are occupationally acquired, despite Hep B being 95% preventable by immunization.[8,9] Individuals unvaccinated against Hep B have a 30% risk of seroconversion in the setting of percutaneous injury, whereas effective antibody response reduces transmission to <5%.[10] The Hep C seroconversion rate is 1.8% for a single needlestick.[7,10] There is no vaccine for Hep C, though recently an antiviral treatment regimen was developed that has approximately 90% effectiveness in curing acute Hep C and preventing chronic Hep C infection.[11] Unfortunately, antiviral treatment remains expensive and does not start until after the employee has tested positive for Hep C, creating undue psychological stress and financial burden to the infected HCW.[11,12]

HCWs in surgical specialties have the most procedural exposure to sharps also have disproportionately higher risk of sharps injury.[13-18] However medical trainees (medical students and resident physicians) are at particularly elevated risk of injury due to intrinsic and extrinsic risk factors.[13,18-21] Multiple cross-sectional studies demonstrate that medical trainees as a whole have higher rates of sharps injury than attending physicians, with residents sustaining higher rates of injury than medical students.[13,21,22] International rates of medical trainee needlestick injury (NSI) rates fall within this range, with an estimated rate of 23% in Germany[23], 25% in Canada[24] and 39% in Iran[25] in selected studies.[23-25]

Troublingly, the Centers for Disease Control (CDC) estimates half of needlestick injuries go unreported, unrecorded and therefore untreated.[1] The most frequently cited reasons include the patient being deemed low-risk by the injured worker, fear of repercussion or shame, and lengthy or complex reporting procedures.[13-15,26-28] Medical students as well as residents and fellows report less of their sustained needlestick injuries than do attending physicians, with less experienced medical trainees reporting the least frequently.[13-15,26,27,29]

Although the majority of NSIs do not result in HCW infection by a bloodborne pathogen, each needlestick injury is still quite costly in terms of clinical time, economic impact and emotional burden to healthcare workers, trainees, and their families.[12,30] The estimated cost is $199-1691 per needlestick injury with a large portion of this is in direct post-NSI medical costs.[12] However, this estimate does not consider the cost of prescription treatment if necessary, compensation or potential litigation. For example, treatment of a single Hep C HCW seroconversion, although ~90% curative, still ranges from $50,000-90,000 for the 12-week course of treatment.[11] The cost of medication alone could represent an insurmountable financial burden to injured medical students who are not covered by worker's compensation and are paying for schooling simultaneously. The lifetime cost of HIV treatment is estimated by the CDC to be $379,668, which is particularly prohibitive to a medical trainee who likely has already incurred significant debt.[31] In addition to financial burdens, HCWs report the potential for NSI represents a major humanistic burden in terms of safety concerns and post-NSI many experienced depressive symptoms or persistent anxiety.[12]

Costs to training institutions could include increased number and cost of worker's compensation claims or insurance premiums, lost employee work time, cost of treatment for potential infection, and increased Occupational Safety and Health Administration (OSHA) scrutiny. OSHA does not mandate sharps injury reporting for medical students, who are not employees of hospitals, resulting in incomplete data collection and loss of potentially invaluable risk assessment data.

Prior study of University of South Florida (USF) medical trainees sharps injuries from academic years 2002-2008 established USF baseline NSI data. This study compared more recent data from academic years 2009-2015 to the baseline data from academic years 2002-2008. First, the prevalence of sharps injuries in USF trainees from academic years 2009-2015 was calculated and compared to all prevalence data for USF academic years 2002-2008. Next this data was compared to updated United States (US) training institution data following systematic literature review and recalculation of pooled US data. Lastly, the current data was added to pooled US institutional data as well as previously acquired USF data to form pooled prevalence of percutaneous injuries in US medical trainees. The previous study found a significantly increased risk of percutaneous injury in the first post-graduate year of training (PGY-1) and also in surgical specialties. We anticipate similar trends in academic years 2009-2015.

Chapter 2: Methods

Sharps Injuries Among Medical Students and Residents at USF

A retrospective cohort study was initiated in March of 2018 at the University of South Florida (USF) College of Medicine to determine the prevalence of percutaneous exposures to bloodborne pathogens among medical students and residents training at USF. A starting academic year of 2009 and ending academic year of 2015 was selected because a previous study of the same nature entitled "Sharps Injuries in Medical Training: Higher Risk for Residents Than for Medical Students" evaluated similar data covering academic years 2002-2008, and there was complete availability of these data years for analysis. This study is therefore a continuation of the prior study. Inclusion criteria for this cohort were both medical students and residents (including fellows) training at or employed by USF for the academic years 2009-2015, corresponding to the dates of July 1, 2009 to June 30, 2015. All medical students and residents were considered to be equally at-risk for sharps injuries; none were excluded.

At USF, initial medical trainee education on bloodborne pathogens, like many other U.S. training institutions, included details on risk of exposure, the nature of bloodborne pathogens and transmissibility, and detailed procedures for reporting needlestick injuries or potential bloodborne pathogen exposures. This was accomplished primarily through computer-based training, however there were also face-to-face discussions regarding resources both during and after normal working hours and a discussion of safe practices to reduce potential seroconversion. Meticulous exposure reporting procedures for any potential USF training site were outlined on a laminated card designed to hang behind each trainee's ID badge and were distributed at orientation and installed onto the ID badge clasp. All sharps incidents reported by USF

Health employees or medical students were gathered by USF's Medical Health Administration (MHA) then assembled into the broader USF OSHA-required annual exposure logs. The log contained free-text information regarding date of trainee exposure, department, program, occupation (in this case training year), type of exposure, device involved, and activity description. Detailed post-exposure prophylaxis information, though available in some cases for the previous study, was not available for this study.

The source for USF sharps injury data was thus the previously described USF annual exposure logs for each year. The USF MHA provided copies of the logs that only showed the columns for department, type of exposure, occupation, device and activity. Each year's exposures were divided into Fall (July 1-December 31) and Spring (January 1-June 30) semesters with academic years spanning from Fall of one year to Spring of the following year. Logs in years 2010-2013 were initially kept by calendar year and were maintained in an academic year format starting in 2014 but were converted into academic years as described. Thus, no data was lost overlooked in this transition due to the time frames set by the nature of this study. The University of South Florida's Institutional Review Board (IRB) reviewed the proposed study protocol and certified it exempt under 45 CFR 46.102 in March of 2018 and data collection and analysis began immediately.

Cases were defined as either medical students or residents/fellows who reported a percutaneous exposure described as a needlestick, puncture, cut, laceration, or scrape that occurred during the study period. The cases were entered onto a Microsoft Excel (version 16.11) spreadsheet by year and semester, using "MS-X" or "PGY-X" for medical student or resident respectively where X represents the year of training if given, department, and device.

A wide variety of post-graduate medical training programs are offered by the USF. For analysis purposes, the programs were grouped for similarity and in the same manner as the prior USF study for direct comparison purposes. The first category was the Medicine Department, which included Dermatology, Family Medicine, Internal Medicine, Emergency Medicine, Neurology, Physical Medicine and Rehabilitation (PM&R), Preventive/Occupational Medicine, and Psychiatry to include all fellows in these subspecialties. Surgery included General Surgery, Orthopedic Surgery, Urology, Neurosurgery, Otolaryngology, Vascular Surgery, and Plastic Surgery, with all fellowships and subspecialties therein. The remaining specialties were evaluated independently: OB/Gyn, Ophthalmology, Pathology, Radiology, and Pediatrics. The Anesthesiology training program was previously evaluated however was no longer active during the time period of this study and no data was available for this program from the 2009-2010 academic year onward.

First, we established the prevalence of sharps injuries (excluding mucocutaneous exposures) in both medical students and residents at USF for this time period. The overall prevalence was calculated by dividing the number of period percutaneous injuries by total number of trainees separated broadly into medical students and residents for years 2009-2015. Pooled prevalence by program (i.e. Medicine department, Surgery etc.) was calculated using the same method. Next, prevalence of percutaneous injuries by training level were calculated using the same method, only grouped by training level. First and second year medical students (MS 1/2) were grouped, third and fourth year medical students (MS 3/4) as well, first year post-graduate students (PGY-1s), PGY-2s PGY-3s, and finally PGY-4's and above were grouped together for analysis. Descriptive statistics were calculated using Microsoft Excel version 16.11.

The Cochran-Mantel-Haentzel (CMH) chi-square test was used to look for significant percutaneous injury differences within programs between academic years. Chi-square testing was also used to look for inter-program variability of sharps injury prevalence by academic year. Then differences within programs by level of training were evaluated using chi-square analysis. Percutaneous injury rates by department were then compared with the College of Medicine (COM) percutaneous injuries for the same time period (2009-2015) using a Chi-square test. Percutaneous injuries by department in the current study (2009-2015) were then compared to injury rates in each department as reported in the 2002-2008 cohort and evaluated for significance using a chi-square testing. Chi-square testing was also used to look at differences between percutaneous injury rates within programs from academic years 2002-2009 as compared to academic years 2009-2015. CMH chi-square testing for trend was used to look at sharps injury data by training level. A $p<0.05$ was considered significant for each test.

Odds ratios (OR) of percutaneous injury were calculated by program, with the USF COM students as the comparative baseline (1.00). Standard deviation and 95% Confidence Intervals (95% CI) were also calculated.

Sharps Injuries Among Medical Students and Residents at Other US Institutions

As in the previous study, systematic literature review was conducted to identify studies accomplished in US institutions giving prevalence of sharps injuries in medical trainees. A literature search was conducted in PubMed (Medline) for articles relating US institution medical trainees reporting prevalence of sharps injuries and published Post-Needlestick Safety and Prevention Act (NSPA) of 2000. The PubMed search was accomplished in January 2018 using search terms (Percutaneous OR needlestick OR sharps) AND (students OR interns OR residents OR house staff OR trainee), limited to 1/1/2001 and later. The search yielded 231 publications for abstract review. Studies of non-US institutions were excluded (167). Sixty-four (64) additional studies were excluded on the basis of being off-topic, lacking prevalence reporting in medical trainees, or being letters/editorial commentary. The remaining articles were reviewed, and data were analyzed in depth to establish prevalence of sharps injuries in the US as well as prevalence of underreporting of sharps injuries at US institutions. Data extraction from the selected articles included: author(s), date of publication, source data, study population, number of trainees assessed during the period of study, total number of sharps injuries reported (excluding mucocutaneous injuries where applicable), and percentage of underreporting of needlestick injuries when available. In the previous USF study (2002-2008), 10 studies were selected for in-depth review and prevalence calculation; these studies were also reviewed in detail for the current study. An additional 6 studies were selected for in-depth review, data analysis and pooled prevalence analysis. Following data extraction, data was divided into survey-type studies versus studies that evaluated exposure log-based data. Survey studies' mean prevalence of underreporting was pooled and separated by medical trainee subgrouping (Medical Students vs. Residents/Fellows).

Sharps injury prevalence acquired from survey-based studies was calculated separately in medical students and resident using sharps injuries in the numerator and total trainees as the denominator. Prior to adjustment for underreporting on exposure log-based studies, crude prevalence of sharps injuries from exposure log-based studies was computed using number of injuries as the numerator and total trainees as the denominator. One report provided number of sharps injuries separated by medical students and residents, however only a combined denominator for all medical trainees (both medical students and residents/fellows combined), therefore no calculable rate was available and this data was excluded from further data calculations. This study was still presented in Table 2 for interest and comparison.[33]

Underreporting in exposure-based studies was then accounted for by calculating separate mean underreporting rates for medical students and residents/fellows from survey-based studies. Each underreporting rate was then applied to each category of exposure log-based survey, resulting in a best estimate of true number of sharps-injured trainees in each exposure log-based study.

Pooled Prevalence of Sharps Injuries among US Students and Residents

Pooled sharps injury prevalence of medical students was calculated using all survey and exposure log-based surveys (adjusted for underreporting). Pooled prevalence of resident/fellow sharps injuries was also calculated using all survey and exposure log-based surveys (adjusted for underreporting). Pooled prevalence of medical students sharps injuries and resident/fellow sharps injuries were compared by student's t-test, using a $p<0.05$ as significant. Odds ratio and 95% CI of resident/fellow prevalence to medical student prevalence was also calculated.

Chapter 3: Results

Sharps Injuries Among Medical Students and Residents at the University of South Florida (USF)

For this study period, 3992 medical students were enrolled at the USF College of Medicine (COM), this includes all years of training, both 1st and 2nd (non-clinical) and 3rd and 4th (clinical). USF Graduate Medical Education (GME) employed 4, 577 residents in all specialties in the 2009-2015 academic years. 727 total blood and body fluid exposures were reported in medical trainees (medical students and residents/fellows) during the study period, with medical students accounting for 84 or 11.6%. A total of 619 (85.1%) of the reported exposures were percutaneous injuries, with medical students accounting for 74 or 12.0% of percutaneous injuries. There were no reported bloodborne pathogen infections in USF medical trainees during the study period.

Overall data from this study indicated that USF residents were over 7 times more likely than medical students to sustain a percutaneous injury (Odds Ratio (OR)=7.19, 95% CI 5.62-9.21). This appears to be increased from 2002-2008 academic years, which reported residents having an OR of percutaneous injury compared to medical students of 4.58 (95% CI 3.62-5.87), however there was no statistically significant difference between these odds ratios (p=0.65) by chi-square testing.

Period prevalence of percutaneous injuries in medical students in the previous data set was 2.7% (95% CI 2.21-3.35); period prevalence for sharps injuries in medical students this 7-year study period was 2.1% (95% CI 1.51-2.58%) and there was no significant difference in medical student reported sharps injury prevalence. In USF residents, prior period sharps injury prevalence (2002-2008) was 11.4% (95% CI 10.47%-12.44%) whereas period prevalence for this study (2009-2015) was 12.06% (95% CI 9.76%-14.36%), again demonstrating no significant differences. Prevalence of sharps injuries in medical students and residents across all prior and currently studied years at USF are shown in Figure 1. Cochran-Mantel-Haentzel (CMH) Chi-square (χ^2) testing demonstrated no significant trends across years within groups, however there was a statistically significant difference between pooled medical student sharps injury prevalence and resident/fellow sharps prevalence (t-test, p<0.0001).

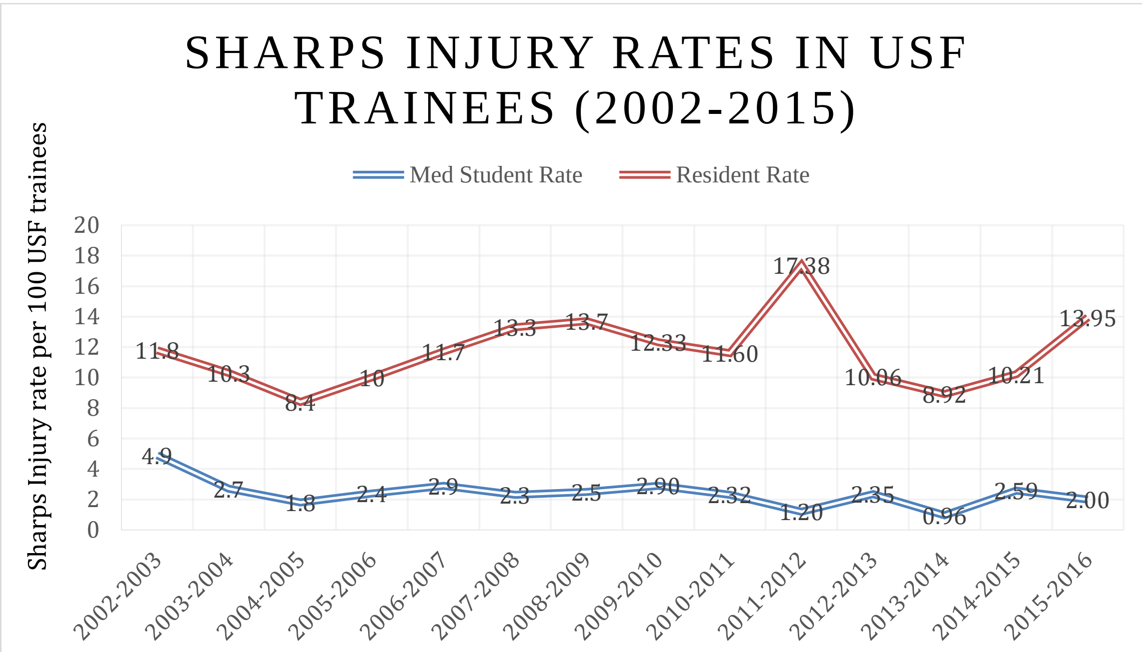

Figure 1: Annual sharps injury rates in USF medical trainees from 2002-2015

Regarding MSs, MS 1/2s (non-clinical) accounted for 11.2% of medical student sharps injuries, leaving 88.8% of injuries accounted for by clinical MS 3/4s. Only 3 (2.9%) reported MS incidents lacked complete data pertaining to the injured student's training year. Clinical MSs had an increased likelihood over non-clinical MSs of sustaining percutaneous injury with OR=9.17 (95% CI 4.37-19.21).

Regarding resident data, 16 (2.5%) entries did not specify percutaneous or mucocutaneous exposure. Of those not specified, 1 entry simultaneously did not specify the resident's post-graduate year of training. Of known percutaneous injuries, 19 (2.9%) did not specify the resident's year of training and 3 (0.5%) mucocutaneous injuries did not record the resident's year of training.

Resident rates of sharps injuries by department in descending order of proportion were Surgery, OB/Gyn, Pathology, Ophthalmology, Radiology, Medicine Department, Pediatrics and finally Psychiatry with no injuries. Each department demonstrated a significantly increased risk over medical students for sharps injury with the exception of Pediatrics ($p=0.001$) and Psychiatry ($p=0.000$) (Table 1). When comparing sharps injury rates by program from 2002-2008 to the current study using a Chi-square test, there were statistically significant increases in injury rates in this study for the Surgery department ($p= 0.005$) and the Pediatrics Department ($p= 0.0131$).

Table 1: Sharps injury prevalence among USF medical trainees by department, 2002-2008 and 2009-2015

	2002-2008				2009-2015				
Department	***Trainees***	***Sharps Injuries***	***Sharps Injuries per 100 trainees (95% CI)***	***Odds Ratio (95% CI)***	***Trainees***	***Sharps Injuries***	***Sharps Injuries per 100 trainees (95% CI)***	***Odds Ratio (95% CI)***	***X^2 p-value***
COM	3142	86	2.8 (2.2-3.4)	1	3992	71	1.779 (1.32-2.38)	1	
Surgery	695	198	28.5 (25.3-32.0)	14.16 (10.8-18.6)	846	298	35.23 (26.51-43.94)	28.79 (21.97-37.73)	***0.0049***
OB/Gyn	174	44	25.3 (19.4-32.3)	12.03 (8.0-18.0)	181	53	29.28 (20.72-37.84)	21.92 (14.77-32.55)	0.3985
Pathology	135	24	17.8 (12.2-25.2)	7.7 (4.7-12.6)	126	31	23.02 (14.73-31.30)	15.82 (9.83-25.47)	0.1067
Ophthalmology	83	16	19.3 (12.1-29.2)	8.5 (4.7-15.3)	86	9	10.47 (6.36-14.57)	6.19 (2.98-12.84)	0.1767
Radiology	246	13	5.3 (3.0-8.9)	1.98 (1.12-3.72)	325	28	7.69 (4.32-11.07)	4.41 (2.76-7.06)	0.1249
Medicine	1691	99	5.9 (4.8-7.1)	2.21 (1.70-3.08)	2574	118	5.08 (1.94-8.22)	2.83 (2.11-3.81)	0.1268
Pediatrics	430	3	0.7 (0.1-2.1)	0.25 (0.08-0.78)	439	13	2.96 (1.56-4.36)	1.61 (0.88-2.94)	***0.0131***
Psychiatry	236	2	0.8 (0.0-3.2)	0.30 (0.07-1.22)	251	0	0	0	0.1456

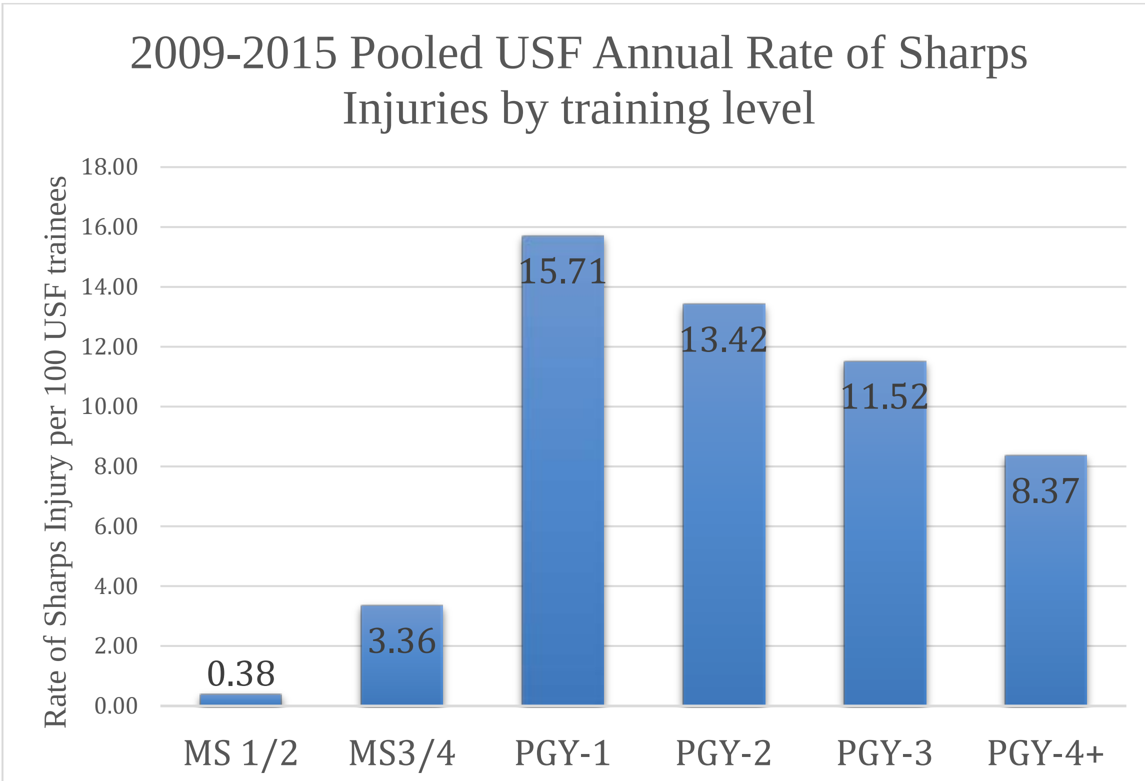

Figure 2: USF medical trainees' annual rate of sharps injury by training level (2009-2015)

For the USF College of Medicine (COM), MS 1/2s had a sharps injury prevalence of 0.38% (95% CI 0.06-0.74%) and for MS 3/4s, the prevalence was 3.25% (95% CI 2.33-4.18%). For pooled USF GME training programs from 2009-2015, the rate of sharps injury in PGY-1s was 15.71% (95% CI 4.1-27.52%); PGY-2s 13.42% (95% CI 3.21-22.60%); PGY-3s 11.52% (95% CI 2.20-20.83%), and PGY-4s and above 8.37% (95%CI 1.5-15.2%). Cochran-Mantel-Haentzel (CMH) chi-square testing showed a significant difference between training levels ($p<0.0001$), with two-sample t-tests between each training level ($\alpha=0.05$) demonstrating significant differences only between MS 1/2 and PGY-1s, PGY-2s, and PGY-3s (Table 2). There were no statistically significant differences between any other groups of trainees using CMH/t-test.

Table 2: t-test p-values comparing USF medical trainees by experience level

	MS 1/2	MS 3/4	PGY-1	PGY-2	PGY-3	PGY-4
MS 1/2		*0.0001*	*0.0242*	*0.016*	*0.0368*	0.416
MS 3/4	*0.0001*		0.0591	0.0508	0.1086	0.1733
PGY-1	*0.0242*	0.0591		0.7523	0.5668	0.2763
PGY-2	*0.016*	0.0508	0.7523		0.7648	0.3711
PGY-3	*0.0368*	0.1086	0.5668	0.7648		0.5774
PGY-4+	0.416	0.1733	0.2763	0.3711	0.5774	

Cochran-Mantel-Haentzel (CMH) followed by two-sample t-test can lend false positive results (inappropriately reject the null hypothesis).[44] Sound statistical technique requires utilization of the one-way ANOVA to evaluate differences in means, followed by Tukey-Kramer post-hoc analysis to compare each of the groups separately.[44] One-way ANOVA demonstrated a significant difference between groups, however Tukey-Kramer post-hoc analysis did not show significant differences between any of the comparative groups. Cochran-Mantel-Haentzel (CMH) Chi-square (χ^2) testing looking only at pooled resident medical trainees from PGY-1 onward did find a statistically significant decreasing trend throughout residency training (p=0.000).

While USF residents across all training programs demonstrated decreasing trend in rate of sharps injury as training and experience progressed, when separated out by program, this was not uniformly the case (see Figure 3). Surgery had the highest overall sharps injury rate, however Pathology had the highest PGY-1 sharps injury rate at USF. OB/Gyn showed increased rates of sharps injury in PGY-2s and PGY-3s. Medicine showed a small upward trend in sharps injury reports as level of training increased, opposite of the pooled downward trend for sharps injuries as training progresses.

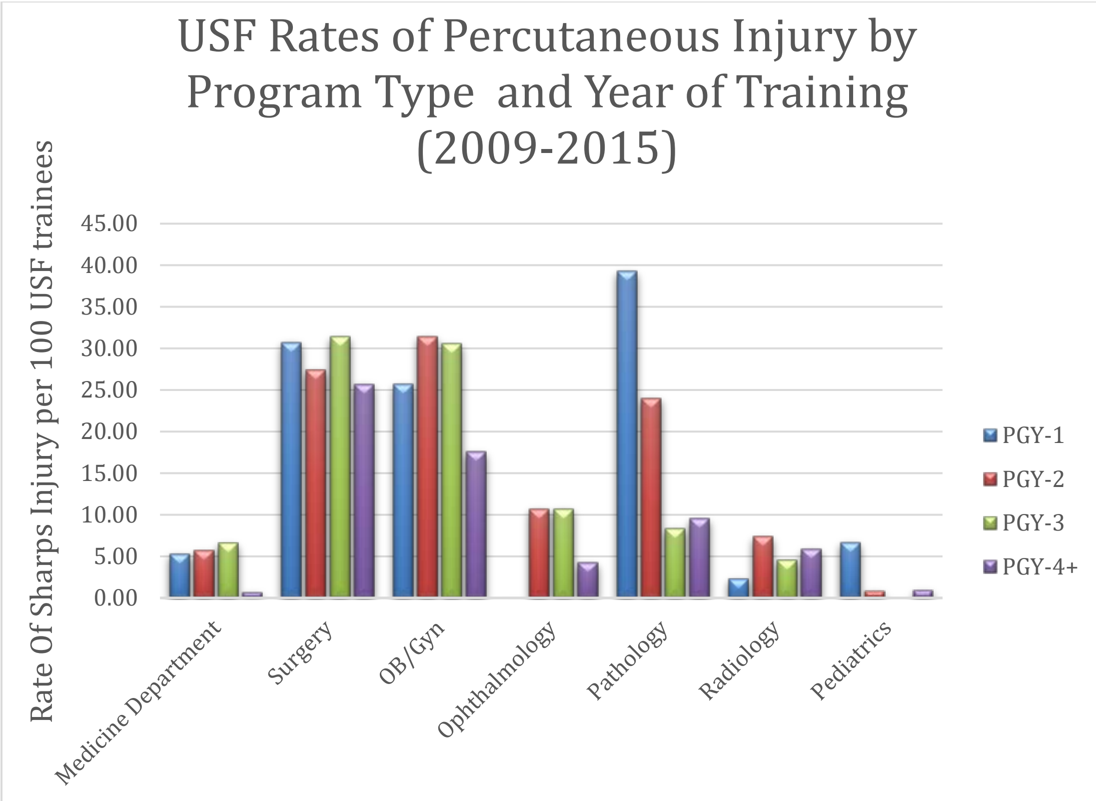

Figure 3: Percutaneous injury rates by training year and program (2009-2015)

Percutaneous or sharps injuries are caused by multiple types of objects from suture needles, to hollow-bore needles to surgical hardware. Out of 619 medical trainee sharps injuries, 592 (95.6%) recorded device type. Injuries were grouped by injuring object into: suture needles, hollow-bore needles, scalpels, instruments/hardware, and other sharps. Overall 308 (49.8%) incidents involved suture needles; 102 (16.5%) involved hollow-bore needles, 69 (11.2%) involved scalpels, 74 (12.0%) involved instruments/hardware, and 39 (6.3 %) were classified as other devices. There was variability in primary device type implicated by department and this is demonstrated graphically in Figure 4. Surgical, Ob/Gyn and Ophthalmology residents had a predominance of suture needle incidents, while Pathology had a predominance of injury by scalpels. The subgroup with the largest proportion of suture needle injuries was medical students where 61 (78%) of injuries were accounted for by this type of sharp.

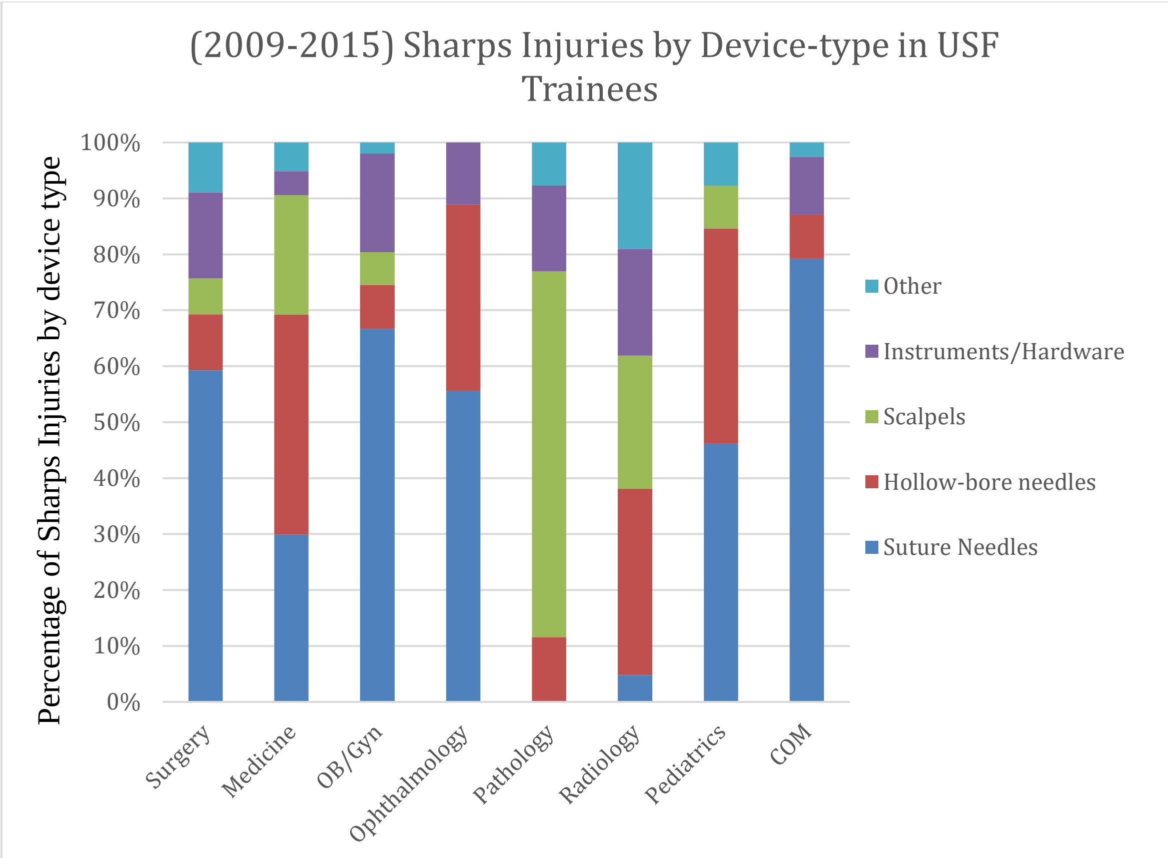

Figure 4: Device-type involved in sharps injury by department (2009-2015)

Percutaneous injuries by department type in the current study (2009-2015) were compared to injury rates in each department as reported in the 2002-2008 cohort using a chi-square. Significant differences from the previous cohort were noted only in the following programs: Surgery and Pediatrics. Surgery had a statistically significant increase from 2002-2008 to 2009-2015 (p=0.0052); Pediatrics also saw a statistically significant increase in percutaneous injuries in the 2009-2015 cohort over the previous cohort (p=0.0202).

All program's sharps injury rates (2009-2015) with exception of Psychiatry had a statistically significant difference when compared to the 2009-2015 COM cohorts' rate of percutaneous injury using chi-square testing.

Sharps Injuries Among Medical Students and Residents at other US institutions

A collection of 16 studies were selected and reviewed in detail to draw conclusions regarding sharps injury prevalence in medical trainees across the US as well as mean underreporting rates of these sharps injuries. All data extraction is summarized in Table 3 and Table 4.

Ten (10) of the selected studies were survey-based studies (Table 3). 3 studies looked specifically at medical students, 2 studies evaluated only residents, 3 studies evaluated sharps injuries in both residents and medical students, and 2 studies considered both medical trainees and other healthcare workers. Evaluating only survey-based studies, the mean prevalence of sharps injuries in medical students was 44% (95% CI 40.8-46.3%) and 73% in residents/fellows (95% CI 71.5-75.4%).

Eight (8) of the survey-based studies also gave a percentage of underreporting of sharps injuries. Based on this sampling of studies, medical students failed to report an average of 52% of their sharps injuries (95% CI 42.5-61.4%) and residents/fellows failing to report an average of 35% of sharps injuries (95%CI 19.9-50%). The difference in underreporting between students and residents was not statistically significant (p=0.459).

The remaining 6 studies, data from the previous USF study (2002-2008), and data from the current USF study (2009-2015) are exposure log-based and data is compiled in Table 4. The 2011 Massachusetts sharps injury surveillance system report data[33] is also presented in Table 4; however, data was not used in the calculations as there was no distinct denominator for medical students versus resident trainees. Three (3) of the studies (including prior USF medical student data) evaluated medical student injury rates. Three (3) studies looked specifically at resident/fellow sharps injury rates (including prior USF resident data). Exposure log-based studies indicated medical student mean sharps injury prevalence of 3.41% (95% CI 2.14-5.84%) and resident prevalence of sharps injury of 25.70% (CI 2.47-49.00%), which due to wide variation in sharps prevalence (reported) have significantly overlapping confidence intervals and are not statistically significant (p=0.418).

Pooled Prevalence of Sharps Injuries Among US Students and Residents

All exposure log-based study data was adjusted by category (MS of Resident) in accordance with predicted underreporting (obtained from survey-based studies) and pooled with the current USF study data to obtain pooled prevalence of sharps injuries in US medical institutions. Pooled prevalence of US medical student sharp injury prevalence and USF data from years 2002-2015 was 6.4% (95%CI 2.4-10.2%). USF medical students (2009-2015) had a lower reported prevalence of sharps injury than US pooled data of 1.78% (95%CI 1.32-2.38); if accounting for underreporting, as is done in the pooled US prevalence data, USF medical students would have a sharps injury rate of 3.86%. USF residents did not differ statistically from pooled US resident sharps injury rates. USF resident's sharps injury rate was 11.94% (95% CI 9.87-14.01%) versus US pooled resident sharps injury prevalence of 34.2% (95% CI 6.9-61.4%). USF resident rate of sharps injury accounting for predicted underreporting is 18.3%. There was no statistical difference between pooled medical student and resident injury rates (p=0.0941).

Table 3: Survey-based studies assessing prevalence of sharps injuries in US medical trainees (since 2001)

Author(s), Year of Publication	Study population	# of trainees	# of injuries	# (%) of unreported injuries	Underreporting Average
Birenbaum et al, 2002[27]	3rd-year medical students from University of Florida	119	24	14 (58%)	Medical Students 52% (42.5-61.5%)
Chen et al, 2008[34]	3rd-year medical students from at New York-Presbyterian Hospital/Weill Cornell medical center	75	7	Not given	
Patterson et al, 2003[26]	3rd and 4th year medical students at Washington University School of Medicine	143	59	24 (41%)	
Kessler et al, 2011[14]	Healthcare Workers at University of Illinois medical center (MS data)	144	9	6 (67%)	
Sharma et al, 2009[28]	Surgery residents at 17 training programs (injuries as Medical Students)	699	415	297 (51%)	
Bernard et al, 2011[29]	Orthopedic Residents/Medical Students at The Johns Hopkins University (MS data)	53	15	6 (43%)	
Makary et al, 2007[13]	Surgery residents at 17 training programs	699	582	297 (51%)	Residents 35% (19.9-49.8%)
Kessler et al, 2011[14]	Healthcare Workers at university of Illinois medical center (Resident data)	106	47	16 (34%)	
Zuraw et al, 2012[35]	Emergency medicine residents at University of California Irvine and Presence Resurrection Medical Center in Chicago	208	115	76 (37%)	
Donnelly et al, 2013[36]	Dermatologists at ACGME accredited training programs (Resident data)	96	72	27 (37%)	
Green-Mackenzie et al, 2016[4]	Healthcare Workers at University of Pennsylvania (Resident data)	155	131	Not given	
Bernard et al, 2011[29]	Orthopedic Residents/Medical Students at The Johns Hopkins University (Resident data)	23	19	0 (0%)	
Sharma et al, 2009[28]	Surgery residents at 17 training programs (injuries as Residents reported)	699	493	297 (51%)	

Table 4: Exposure log-based studies assessing prevalence of sharps injuries in US medical trainees (since 2001)

Author(s), Year of Publication	Study population	# of trainees	# of injuries	Best estimate for # injuries, adjusted for underreporting	Pooled Injury rates
Trapé-Cardoso & Schenk, 2004[37]	Healthcare workers at Univ of Connecticut (medical/dental)	2445	142	296	
Askew, 2004[19]	Students at medical schools in Virginia (data for Univ of Virginia and Virginia Commonwealth Univ shown)	23458	393	819	Medical Student 6.2% (2.4-10.2%)
Previous USF study (2002-2008)	Medical students at University of South Florida	3142	86	179	
Current USF study (2009-2015)	Medical students at University of South Florida	3992	74	154	
Dement et al, 2004[18]	Healthcare workers at Duke University Health System (Resident data shown, no. of injuries calculated from rate and FTEs)	3792	626	961	
Brasel et al, 2007[20]	Surgical residents at Medical college of Wisconsin	240	118	181	
Previous USF study (2002-2009)	Residents/Fellows at University of South Florida	3982	455	698	Residents 34.2% (6.88-61.4%)
Current USF study (2009-2015)	Residents/Fellows at University of South Florida	4577	545	837	
Massachusetts sharps injury surveillance, 2011[33]	Medical trainees in Massachusetts (Med students and Residents/Fellows from 2002-2009) (no. of injuries calculated from rate and RTEs)	44656	3769 (MS 345) (Res 3124)	5875 (MS 530) (Res 4798)	

Chapter 4: Discussion

The United States Centers for Disease Control (CDC) estimates approximately 385,000 annual sharps injuries in hospital-based healthcare workers (HCWs), averaging to over 1,000 sharps injuries daily.[1,2] The World Health Organization (WHO) provides a probability-based model for assessment of risk for BBP transmission in the HCW population via sharps injury.[30] This model addresses risk factors for occupationally acquired BBP which include: prevalence of infection in the population, susceptible proportion of healthcare workers, risk of transmission following exposure, and rate of sharps injuries.[30] The prevalence of infection in the treated population is not easily changed, and in fact is estimated to be much higher in urban surgical populations than in the general population, however the susceptibility of HCWs is modifiable by vaccination in the case of Hep B, timely treatment by HIV post-exposure prophylaxis (PEP), and a 12-week antiviral regimen for Hep C if seroconversion occurs.[38] The rate of sharps injury itself is significantly modifiable through practice change, safety-engineered devices (SESDs) and potentially by procedural experience or training. In fact, since the passage of the Needlestick Safety and Prevention Act of 2000, there has been a 31% reduction in sharps injuries outside of operating room (OR) settings, with an estimated reduction of more than 100,000 HCW needlestick incidents annually and a cost savings of $69-415 million.[16,39] Application of the WHO risk assessment model to USF data, given residents were found to have sharps injury OR=7.19 compared to medical students, demonstrates greater than a 6-fold increased risk of BBP infection by percutaneous injury in residents over medical students.[30]

Risk factors for sharps injury have been studied and are frequently present in medical trainees, particularly medical students and junior residents. These factors include experience <4 years, fatigue while at work, and age <45 years.[18,40,41] Medical trainees also have less developed procedural skills and dexterity than their more experienced physician counterparts. One study demonstrated that surgical residents who sustain needlesticks during medical school are more likely to sustain needlestick during residency, while other studies have not found sharps injury in medical school corollary with sharps injury in surgical residency.[15,28] It is also likely that those interested in surgical specialty training are participating in more surgical and procedural opportunities in medical school, increasing their risk of injury.[27] HCWs in procedural specialties have increased exposure to sharps. Increased sharps usage is a critical risk factor for sharps injury as many studies have demonstrated that the prevalence of having had at least one potential BBP exposure in surgical trainees by the end of training is 100%.[13,15,29] Lack of availability of SESDs and low utilizations of SESDs also contribute to an unsafe workplace.[4,17,42] The type of SESD available may affect both its implementation as well as its effectiveness. A 15-year review of sharps injuries since the passage of the NSPA of 2000 demonstrated an overall decrease in sharps injuries but an increasing rate of injury by SESDs, which may be due to the lack of passively activated SESDs.[43] Therefore ensuring availability safety devices with human factors in mind as well as ensuring that SESDs meet end-user clinical requirements, safety goals, and user preference is an important consideration in preventing sharps injury.

Sharps Injuries Among Medical Students and Residents at the University of South Florida (USF)

Resident and medical student injury rates vary across training years, though no statistical trend or difference between years was seen in this study (Figure 1). Despite lack of statistical significance in this study's trend data, there was an apparent increase in resident injury rates in the 2011-2012 academic year. One potential explanation for this increase is that the previous USF study data (2002-2008) was widely disseminated among GME programs and presented in multiple venues to residents during the Spring of 2011, perhaps resulting in increased resident sharps injury reporting throughout the following semesters. Alternatively, it is possible that sharps injuries increased in the 2011-2012 academic training year for reasons unknown.

Pathology again demonstrated extremely high rate of injury by scalpel, as in the prior USF study, indicating the need for further evaluation and intervention into safety in this GME setting. Also similar to the findings of the prior USF study, surgical specialties demonstrated a particularly high propensity for sharps injury by suture-needles or solid-bore needles. This observation is consistent with other studies that reported continued high rates of solid-bore needle injury to surgeons and resistance to adoption of the American College of Surgeon's (ACS) recommendations for double-gloving, a hands-free zone, and use of blunt-tip suture needles.[17,42] Compliance remains low regarding the use of blunt tip suture needles, with physicians reporting <10% compliance with this recommendation and simultaneously citing lack of availability of blunt-tip suture needles as the primary driver of non-compliance.[17] Following modification of the BBP OSHA standard by the NSPA of 2000, overall rates of sharps injuries in HCWs have decreased by almost 1/3, yet surgeons have experienced a 6.5% jump in sharps injury since that time.[16] Most needlestick injuries in surgeons occur with solid-bore needles used in the operating room, bolstering support for more widespread use of blunt-tip suture needles.[28,49] The use of blunt-tip needles for safety of the surgeon still must be balanced with benefit to the patient and patient safety, thus may not always be feasible. Offering a higher-level solution to this workplace hazard still, Makary et al estimated 25% of surgical procedures could be accomplished with entirely sharpless technique over 10 years ago.[13] Griswold et al studied sutureless central line securing techniques (StatLock™) by residents and found that 5.25 sharps injuries and $57,000 could have been prevented or saved over a 4 year period by use of this kit over traditional central venous catheter kits.[42] Prohibitive factors for the use of sharpless or sutureless systems noted in a focus group included: lack of training in HCWs, apprehension regarding the device's effectiveness, and efficacy-supporting literature being associated with sharpless device manufacturers.[42] This focus group and many studies also support the need for adequate training of HCWs, the need for ample opportunity for procedural practice and mastery of techniques with safety-engineered devices, adequate risk education and simplistic reporting procedures.[18,28,33,37,42,49]

Excluding medical students from analysis, there was a high rate of sharps injury in the first post graduate year followed by a steady decrease in rate of percutaneous injury as training experience progressed using CMH chi-square testing for trend (p=0.000, Figure 2). Many studies including the previous USF study (2002-2008) report a trend demonstrating increased sharps injury rates in PGY-1 trainees that subsequently decrease as training progresses.[14,20] There are other studies that do not support this trend.[13,15] Still, there exists a reasonable hypothesis of the protective effect of procedural experience, potentially due to improved dexterity and procedural technique.

In comparison to US pooled data, USF medical students' exposure-logged sharps injuries were not significantly different, with a sharps injury rate of 3.86% accounting for underreporting, which falls within the confidence interval of the US pooled prevalence of 6.4% (95%CI 2.4-10.2%). USF residents also did not differ statistically from pooled US resident sharps injury rates. USF resident's sharps injury rate accounting for underreporting was 18.3% versus US pooled resident sharps injury prevalence of 34.2% (95% CI 6.9-61.4%).

Simulation-based training

In keeping with the experience hypothesis, intensive simulation-based training should offer a theoretical method for reduction of risk, similar to that offered in aviation training by high-fidelity flight simulators. Near-real-world flight simulators allow a pilot to simulate takeoff, flight and landing so realistically that the hours spent training on some simulators count toward officially logged flight hours the same as flying a physical airplane.[45] The aviation industry has made significant strides in reduction of accident rates, achieving and accident rate of 1.08 accidents per 1 million flights; demonstrating safety rates orders of magnitude safer for patient and provider than most medical procedures or hospitalization (estimated medical error rate per hospitalization of 1 in 10).[46,47]

Based on outstanding safety achievement in the aviation industry accomplished in close conjunction with realistic simulation, medicine ought to strongly consider the potential safety improvements simulation based training can offer. In early spring of 2012, the University of South

Florida's Center for Advanced Medical Learning and Simulation (CAMLS) opened. This state-of-the-art simulation training center in downtown Tampa specializes in, "providing a realistic training environment for healthcare providers".[48] This center allows USF residents and medical students opportunities to participate in simulation-based training on manikins in a multitude of settings from mass casualty response training to procedural skills acquisition in an environment free of BBP transmission risk by sharps injury. Notably, reported sharps injury rates did fall after the opening of CAMLS in spring 2012 (Figure 1). The correlation of sharps injury rates and simulation-based training at USF would be an area of interesting future study.

Limitations

Limitations of studying sharps injuries include reliance on survey-based studies to establish both frequency of sharps injury and also underreporting habits of HCWs. Survey studies are subject not only to recall bias, but also to selection bias in that the population interested in participating may be disproportionately afflicted by sharps injury. The current USF study utilizes pooled data from multiple survey-based studies to construct a best-estimate for likelihood of underreporting in medical students and residents and then uses this estimate to infer the actual number of sharps injuries in that population and other exposure log-based studies. In the previous USF-based study, both medical students and residents were thought to have failed to report approximately half of their sharps injuries, consistent with CDC estimates of underreporting in all HCWs. In the survey-based study compilation obtained for this data set, estimates of medical student underreporting remained around 50% while residents' rates of underreporting were closer to 35%. While reported sharps injury prevalence in residents remains higher than in medical students, this may be artificially inflated by virtue of differential reporting frequencies.

One limitation of using exposure-based studies is lack of consistency or agreement on a common denominator for calculating injury rates, compounded by a lack of a national baseline for comparison or consistent and reliable benchmark data.[39] This study attempted to correct for this by comparing the same population using the same methods between 2009-2015 academic years and 2002-2008 academic years.

Though there were minor changes, such as the Anesthesiology training program no longer operating, and slight variations in the level of detail in data collected by the USF MHA, there was excellent direct comparability. Attempting to compare to national baseline data such as EPINet continued to be limited by lack of common denominator in this study.[21] Although EPINet provides annual reports on HCW exposure to blood and bodily fluids, participation by hospitals is voluntary and is thus represents only a sample of US healthcare sharps exposures. This voluntary reporting may introduce bias since hospital management who place a higher value on safety would be more likely to participate.[21] EPINet also publishes sharps injury rates based on a hospital's Average Daily Census (ADC) as the denominator, however average daily census or another surrogate marker for trainee's time "at-risk" other than annual enrollment was not available for the USF Graduate Medical Education (GME) population. The state of Massachusetts has instituted required reporting of sharps injuries (105 CMR 130.1001 et seq.) in HCWs providing care in a hospital or satellite unit covered by the hospital's license and periodically publishes data from the Massachusetts Sharps Injury Surveillance System, which is, like this USF study and the previous USF study, at least comparable to itself. The common denominator reported by the Massachusetts Sharps Injury Surveillance System, however, is full-time equivalents (FTEs).[33]

Disparities in survey-based studies and exposure log-based studies are similar to those discovered in the previous USF study. There were again large differences in both medical student and resident sharps injury rates obtained from survey-based studies and exposure log-based studies. Survey-based studies showed medical students with a 44% and residents with a 73% injury rate, versus exposure log-based studies, which showed medical students at a 3.4% and residents at a 25.7% sharps injury rate. Underreporting is the most likely explanation for variation in sharps injury prevalence between survey-based studies and exposure log-based studies.

Documented reasons for underreporting in medical trainees with sharps injuries include: inconvenience, reporting takes too much time, no utility in reporting, patient deemed low-risk by injured worker, trainee did not want to know results, stigma of having had needlestick.[28,36,50] Many trainees attribute the underlying cause of their sharps injury to inattentiveness, feeling rushed, or fatigue.[28,50,51]

Medical trainees when compared to attending physicians were more likely to cite embarrassment, fear of repercussion or negative perception by others as reasons for not reporting.[36] Acceptance is a critical part of the human psyche, consequently the fear of loss of acceptance may lead to lower rates of reporting in medical students than in residents and lower rates in residents than attending physicians.[14,28,29]

Underreporting injuries or unsafe acts due to fear of stigma is not limited to the medical field. A culture of safety must be developed within the medical field that has management support and worker buy-in. When a worker feels that an injury is their fault, they are less likely to report an injury. The basis for development of culture of safety is viewing the underlying design of the work situation as unsafe rather than focusing on a worker's "unsafe acts".[52] According to James Reason, "workplaces and organizations are easier to manage than the minds of individual workers. You cannot change the human condition, but you can change the conditions under which people work".[53] More important than evaluating the individual for unsafe acts is the understanding that, "human error is not a cause of failure. Human error is the effect, or symptom, of deeper trouble. Human error is…systematically connected to features of people's tools, tasks, and operating systems".[54]

Safety Solutions

The safety-focused hierarchy of controls begins with elimination, followed by substitution, engineering, warnings, administrative measures, followed lastly by personal protective equipment.[52] Solutions closer to the top of the hierarchy are the most effective at reducing risk. An example of elimination of unsafe processes is sharpless surgery, needless systems such as skin closure with Dermabond™, sutureless central line skin securing such as StatLock™, or needless vaccine administration currently in development and testing phases. Substitution can be accomplished by or advanced non-invasive imaging techniques, or the use of robotic surgery. Engineering controls are exemplified by sharps-engineered safety devices SESDs such as self-retracting needles or even by blunt-tip suture needles. Warnings in this field of study are mostly limited to package labeling/alerts at this time. Administrative controls include allowing only those with significant procedural experience perform risky procedures, simulated training, a hands-free zone in surgical suites, or even interventions aimed at modifying extrinsic risk factors such as fatigue in HCWs or equipping HCWs with adequate knowledge of the risk of BBP exposure and how to report injuries. Personal protective equipment (PPE) includes the use of double-gloving, gowns and face shields.

Trainees have demonstrated a lack knowledge regarding risk of BBP exposure, underestimating seroconversion rates of HIV, Hep B, and Hep C after needlestick injury ~90% of the time.[50] In addition to their lack of knowledge, some surveys reveal potentially low rates of vaccination in trainees and HCWs on the whole against Hep B (55-80%), thus lowering trainees' inherent personal protection to BBPs as well as their motivation for reporting.[50,55]

Benefits of reporting include adequate risk assessment as well as treatment and from a systems perspective, detailed knowledge about workplace risk factors. From a personal HCW perspective, pharmacologic advancement has resulted in a triple therapy antiviral regimen that is 80-90% effective in curing Hepatitis C and preventing progression to chronic Hepatitis C.[11] However, timely reporting and appropriate testing guide therapy. Hep C genotype 1 is the most difficult to cure and accounts for 80% of Hep C cases in the US, placing US HCWs at higher risk of chronic Hep C infection.[11] Suggested techniques to increase reporting, particularly in trainees, include adequate education regarding risk, and mandatory disability insurance in medical students.[18,28,33,37,49,50]

Conclusion

In summary, the overall pattern of sharps injuries has remained stable at USF in the past 7 years, with an increased rate of injury in both the Surgery and Pediatrics programs over the previous USF baseline. These and all USF GME programs, as well as Pathology with its high scalpel sharps injury rate should perform a complete safety risk assessment to look for potential change factors to be implemented to reduce risk to medical trainees. Achievement of significant NSI risk reduction would allow USF Health to lead the way nationally in overhauling the safety of the medical education for both patient and provider. Given the airline industry's clear successes with high-fidelity simulation training, more emphasis should be placed on utilization of the state-of-the-art facility (CAMLS) to increase procedural experience prior to being placed in a high-risk situation. It is also vitally important to continue to educate and encourage all USF Health employees and medical trainees to report sharps injuries along with detailed information about the incident including specific device type to assess the workplace in more detail for hazards. The development of a culture of safety must emphasize that the, “sources of error are structural, not personal. If you want to understand human error, you have to dig into the system in which people work. You have to stop looking for people’s shortcomings”.[54]

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