ORIGINAL ARTICLE

Surgical Procedure Characteristics and Risk of Sharps-Related Blood and Body Fluid Exposure

Douglas J. Myers, ScD;[1,2] Hester J. Lipscomb, PhD;[1] Carol Epling, MD;[1] Debra Hunt, DrPH;[3] William Richardson, MD;[4] Lynn Smith-Lovin, PhD;[5] John M. Dement, PhD[1]

OBJECTIVE. To use a unique multicomponent administrative data set assembled at a large academic teaching hospital to examine the risk of percutaneous blood and body fluid (BBF) exposures occurring in operating rooms.

DESIGN. A 10-year retrospective cohort design.

SETTING. A single large academic teaching hospital.

PARTICIPANTS. All surgical procedures (n = 333,073) performed in 2001–2010 as well as 2,113 reported BBF exposures were analyzed.

METHODS. Crude exposure rates were calculated; Poisson regression was used to analyze risk factors and account for procedure duration. BBF exposures involving suture needles were examined separately from those involving other device types to examine possible differences in risk factors.

RESULTS. The overall rate of reported BBF exposures was 6.3 per 1,000 surgical procedures (2.9 per 1,000 surgical hours). BBF exposure rates increased with estimated patient blood loss (17.7 exposures per 1,000 procedures with 501–1,000 cc blood loss and 26.4 exposures per 1,000 procedures with >1,000 cc blood loss), number of personnel working in the surgical field during the procedure (34.4 exposures per 1,000 procedures having ≥15 personnel ever in the field), and procedure duration (14.3 exposures per 1,000 procedures lasting 4 to <6 hours, 27.1 exposures per 1,000 procedures lasting ≥6 hours). Regression results showed associations were generally stronger for suture needle–related exposures.

CONCLUSIONS. Results largely support other studies found in the literature. However, additional research should investigate differences in risk factors for BBF exposures associated with suture needles and those associated with all other device types.

Infect. Control Hosp. Epidemiol. 2016;37(1):80–87

Although studies suggest overall rates of blood and body fluid (BBF) exposures among healthcare workers have decreased,[1] surgical personnel have not experienced such a decrease[2] and remain among the occupations at greatest risk.[3–6] According to Jagger et al,[7] although sharps injuries in the nonsurgical setting have decreased substantially since the passage of the Needlestick Safety and Prevention Act of 2000, reported sharps injuries in the surgical setting have actually increased 6.5%. BBF exposures, therefore, remain a common health risk among healthcare workers, particularly for surgical staff members.[6,8–12]

Many studies focusing on risk of BBF exposures in operating rooms (OR) have examined the effectiveness of safety measures such as double-gloving, the use of blunt suture needles or other safety devices, and neutral instrument passing zones.[4,13–24] Although some studies have examined the characteristics of the surgical procedures,[13–15,18] other studies of BBF exposures have been mostly descriptive, focusing on the distribution of events by categories such as type of exposure, surgical service, occupation, and device type.[6,8,12,25–27] The current study presents descriptive statistics of BBF exposures occurring in the OR and examines properties of the procedures, gathered in administrative data sources, to determine whether these predict the risk of exposure during surgical procedures. Regression models were produced separately for exposures caused by suture needles, which are the devices most commonly involved in exposures in the OR,[6,8,12,17] and those caused by all other surgical instruments to determine whether risk factors differed by device type.

This study is an extension of a pilot study in which 2 years of similar data were gathered and analyzed.[28] The analysis presented here reflects an expansion of the previous study to a total of 10 years of data gathered at the same institution, extracted in a similar manner, and including variables similar to those

Affiliations: 1. Occupational and Environmental Medicine Division, Department of Community and Family Medicine, Duke University Medical Center, Durham, North Carolina; 2. Occupational and Environmental Health Sciences Department, West Virginia University, Morgantown, West Virginia; 3. Division of Biological Safety, Duke University Medical Center, Durham, North Carolina; 4. Department of Orthopedic Surgery, Duke University Medical Center, Durham, North Carolina; 5. Department of Sociology, Duke University, Durham, North Carolina.

Received June 2, 2015; accepted August 30, 2015; electronically published October 5, 2015

 0899-823X/2016/3701-0013. DOI: 10.1017/ice.2015.233

examined in the pilot study. Because 10 years of data were available for this study, trends of rates are reported here that could not be done in the pilot study.

METHODS

Data were derived from the health and safety surveillance system (hereafter referred to as the surveillance system) developed at the institution in 2001 and updated annually throughout the study period. This data set is the product of several ongoing programs that gather data from human resources, occupational medicine, workers' compensation, employee health promotion, and other sources.[29] Linkage of data across data sets permits individual-level data analyses; data are deidentified after linkages are made. This surveillance system provided BBF exposure events, and variables describing them, which occurred in 2001–2010 at the study site. Only events which occurred in the OR were included.

Perioperative data sources providing characteristics of all surgical cases occurring in 3 divisions of the institution were gathered and merged to supplement the surveillance data. BBF exposure events gathered in the surveillance system were matched to the surgical cases in which they occurred. The exposures were restricted to percutaneous events; splashes were excluded. The perioperative data provided the following variables: estimated patient blood loss; urgency of surgical case; department performing the procedure; number and job classifications of OR personnel; procedure start and stop times (used to determine duration and shift); and date.

Estimated patient blood loss for each surgical case was grouped into 3 categories: none, 1–500 cc, 501–1,000 cc, and >1,000 cc. Urgency of the procedure, which considers the maximum time allowed between posting of the case and start of the procedure, was categorized according to study institution's criteria as the following: elective; level 1 ("stat"–within 1 hour); level 2 (within 4 hours); level 3 (within 12 hours); level 4 (within 24 hours); and level 5 (nonelective cases not deemed as of urgency levels 1–4; organ harvesting and transplant procedures included).

The surgical services were grouped as follows: dental surgery, general surgery, obstetrics/gynecology, cardiac surgery, neurosurgery, otolaryngology, orthopedics, ophthalmology, plastic surgery, pediatric surgery, thoracic surgery, and urology. The time that procedures began was used to categorize surgical cases into 3 shifts as follows: 7:00 AM–3:00 PM (first shift), 3:00 PM–11:00 PM (second shift), and 11:00 PM–7:00 AM (third shift). Procedure duration was calculated using start and end times and was categorized into less than 2 hours, 2 to less-than-4 hours, 4 to less-than-6 hours, and 6 or more hours.

OR staff members were categorized with regard to their potential for BBF exposure, namely, as those identified as working in the surgical field. Occupations included in this group included attending surgeon, anesthesiologist, certified nurse anesthetist, scrub nurse, circulator nurse, fellow/resident/student, OR/surgical technician, and other technician.

Finally, calendar year of procedures was identified. Trends by year are reported descriptively; trends are also controlled for in multivariate modeling.

These data were gathered retrospectively from administrative sources not intended for an epidemiologic study. Therefore, some measures that might have been useful for a detailed and theoretically guided assessment of BBF exposure etiology, and potential preventive strategies, were not available for examination.

Data Analysis

The number of surgical procedures and BBF exposures, stratified by potential risk factors, are presented as descriptive statistics. Rates of BBF exposures were calculated per 1,000 surgical procedures, and rates per 1,000 procedure hours were also calculated. Exact binomial and Poisson 95% confidence limits were calculated for these rates, respectively.

Since procedure duration was attainable, Poisson regression models were used to examine associations between BBF exposure rates and the risk factors described above. An "ungrouped" approach to Poisson regression[30] was used to assess properties of procedures while still providing unbiased incidence rate estimates. Events were stratified by device type (suture needles and all other types); separate models were generated to analyze risk of BBF exposure. The annual trend variable was included in models to adjust for possible confounding. This was modeled as a set of indicator variables representing each year. Procedure duration was used as the offset variable; results were reported as adjusted incidence rate ratios and 95% CIs. Likelihood ratio tests were conducted to determine the statistical significance of variables modeled as classes of indicator variables. All statistical analyses were conducted using Stata, version 11 (StataCorp).[31] This study was reviewed and approved by the Duke University Medical Center Institutional Review Board.

RESULTS

A total of 333,073 surgical cases were analyzed (Table 1). The overwhelming majority of surgical cases were elective (89.2%); a similar majority occurred during the first shift (88.5%). Roughly half (52.2%) were less than 2 hours in duration. Orthopedics represented the highest proportion of surgical services (20.7%), followed by general surgery (17.2%). Most cases (70.9%) involved 8–14 personnel in the surgical field during the procedure.

A total of 2,113 BBF exposure events were reported by OR personnel during the study period. Most occurred during elective procedures (86.4%), on the first shift (86.1%), and during procedures with 8–14 workers appearing in the surgical field (82.2%). Exposures occurred most often during procedures lasting 2 to 4 hours (43.6%). Orthopedics had the highest proportion of exposures (21.1%), followed by general surgery (18.2%).

https://doi.org/10.1017/ice.2015.233 Published online by Cambridge University Press

TABLE 1. Surgical Procedure Characteristics and Associated Blood and Body Fluid (BBF) Exposure Rates

Procedure characteristics	BBF exposures	Surgical procedures	BBF exposure rate per 1,000 procedures (95% CI[a])	Total procedure hours	BBF exposure rate per 1,000 procedure hours (95% CI[b])
Estimated patient blood loss[c]					
None	971	214,616	4.5 (4.2–4.8)	400,286.7	2.4 (2.3–2.6)
1–500 cc	763	99,294	7.7 (7.2–8.2)	256,034.0	3.0 (2.8–3.2)
501–1,000 cc	215	12,175	17.7 (15.4–20.2)	47,730.7	4.5 (3.9–5.1)
>1,000 cc	157	5,956	26.4 (22.4–30.8)	29,087.6	5.4 (4.6–6.3)
Urgency of surgical case[d]					
Elective	1,826	297,214	6.1 (5.9–6.4)	651,668.9	2.8 (2.7–2.9)
Emergency: level 1	75	6,347	11.8 (9.3–14.8)	17,923.5	4.2 (3.3–5.2)
Emergency: levels 2–4	155	22,982	6.7 (5.7–7.9)	47,644.9	3.3 (2.8–3.8)
Emergency: level 5	55	6,201	8.9 (6.7–11.5)	16,658.1	3.3 (2.5–4.3)
Shift of procedure start[e]					
First shift: 07:00–14:59	1,820	294,678	6.2 (5.9–6.5)	640,988.2	2.8 (2.7–3.0)
Second shift: 15:00–22:59	185	28,116	6.6 (5.7–7.6)	57,068.4	3.2 (2.8–3.7)
Third shift: 23:00–06:59	108	10,028	10.8 (8.8–13.0)	36,646.4	2.9 (2.4–3.5)
Number of personnel ever in surgical field[f]					
1–7	253	93,194	2.6 (2.4–3.1)	128,265.7	2.0 (1.7–2.2)
8–14	1,737	236,127	7.4 (7.0–7.7)	585,388.6	3.0 (2.8–3.1)
≥15	123	3,777	34.4 (27.2–38.8)	21,048.7	5.8 (4.9–7.0)
Procedure duration[g]					
<2 hours	441	174,022	2.5 (2.3–2.8)	201,018.1	2.2 (2.0–2.4)
2 to <4 hours	921	115,515	8.0 (7.5–8.5)	301,919.2	3.1 (2.9–3.3)
4 to <6 hours	469	32,898	14.3 (13.0–15.6)	155,681.7	3.0 (2.7–3.3)
≥6 hours	282	10,387	27.1 (24.1–30.5)	76,084.0	3.7 (3.3–4.2)
Surgical service[h]					
Dental surgery	6	1,706	3.5 (1.3–7.6)	4,674.0	1.3 (0.5–2.8)
General surgery	385	57,337	6.7 (6.1–7.4)	135,000.1	2.9 (2.6–3.2)
Obstetrics/gynecology	210	23,891	8.8 (7.6–10.1)	46,424.7	4.5 (3.9–5.2)
Cardiac surgery	273	17,817	15.3 (13.6–17.2)	83,232.7	3.3 (2.9–3.7)
Neurosurgery	153	26,874	5.7 (4.8–6.7)	70,468.3	2.2 (1.8–2.5)
Ear, nose, and throat	107	17,713	6.0 (5.0–7.3)	27,754.0	3.9 (3.2–4.7)
Orthopedics	445	69,080	6.4 (5.9–7.1)	156,493.3	2.8 (2.6–3.1)
Ophthalmology	154	54,767	2.8 (2.4–3.3)	73,122.3	2.1 (1.8–2.5)
Plastic surgery	124	15,954	7.8 (6.5–9.3)	36,547.0	3.4 (2.8–4.0)
Pediatrics and subspecialties	44	11,461	3.8 (2.8–5.2)	15,143.8	2.9 (2.1–3.9)
Thoracic surgery	66	14,489	4.6 (3.5–5.8)	31,765.1	2.1 (1.6–2.6)
Urology	145	21,979	6.6 (5.6–7.8)	54,017.4	2.7 (2.3–3.2)
Total	2,113	333,073	6.3 (6.1–6.6)	734,702.9	2.9 (2.8–3.0)

[a]Binomial exact confidence interval.
[b]Poisson exact confidence interval.
[c]With 1,057 missing data.
[d]With 351 missing data.
[e]With 276 missing data.
[f]With 0 missing data.
[g]With 276 missing data.
[h]With 30 missing data.

The overall rate of BBF exposures was 6.3 per 1,000 procedures, or 2.9 per 1,000 procedure hours. Associations with procedure characteristics appear stronger when considering rates per procedures, regardless of duration. However, when rates were calculated per 1,000 procedure hours, crude rates varied less among variable categories. These risk rates, which account for procedure duration, rose steadily across categories of blood loss, number of surgical field personnel, and duration

https://doi.org/10.1017/ice.2015.233 Published online by Cambridge University Press

of procedures. The rates of BBF exposures varied among surgical services and were elevated for the obstetrics/gynecology; plastic surgery; and ear, nose, and throat specialties.

Properties of the BBF exposure events and occupation groups of the staff exposed are described in Table 2. Half (49.0%) of the exposures involved suture needles. Fellow/resident/student represented the largest proportion of events (40.0%), followed by attending physician (27.4%).

Annual trends of BBF exposures rates, stratified by device type, are reported in Figure 1. For each device category, the rate per 1,000 procedure hours is shown (with 95% CI error bars). Suture needle events show a modest increase over the study period. The rate of non–suture needle exposures increased more sharply, particularly after 2006.

Poisson regression model results are presented in Table 3. Both models reported include adjustment for calendar year, which, in both models, was statistically significant at the $\alpha = .05$ level (data not shown). The first Poisson regression model presents results for percutaneous BBF exposures involving suture needles only (n = 1,036). Statistically significant increases were observed with blood loss and number of personnel in the surgical field. The rate varied significantly by procedure duration, but the rate did not increase monotonically across categories. Rates did not significantly vary across categories of procedure urgency ($P = .15$), but risk of BBF exposures was elevated among the emergency (level 1 or "stat") category compared with elective procedures. When urgency was recoded into a single variable representing "stat" vs all other levels, the rate ratio was 1.48 (95% CI, 1.07–2.06) (not shown). The rate also varied significantly among surgical services; 3 of the 11 surgical services showed elevated risks compared with the general surgery referent category. Risk of suture needle–related exposures did not vary across shift.

The second Poisson regression model presents results for BBF exposures involving surgical devices other than suture needles (n = 1,077). Blood loss, number of personnel in the field, and surgical service were associated with risk of exposure involving these other device types. All levels of case urgency had rate ratios higher than the elective referent category, but the pattern differed from that found with suture needle–related exposures. Recoding urgency to a single variable

TABLE 2. Characteristics of Blood and Body Fluid (BBF) Exposure Events and Surgical Staff Injured

	BBF exposures (N = 2,113)	
BBF exposure event and procedure characteristics	**N**	**% Events**
Device associated with BBF exposure		
Suture needle	1,036	49.0
Scalpel blade	155	7.3
Other sharp object	266	12.6
Hypodermic needle w/disposable syringe	110	5.2
Wire	80	3.8
Bovie electrocautery device	42	2.0
Other medical device	184	8.7
Missing or unknown	240	11.4
Type of fluid associated with BBF exposure		
Blood, blood products	803	38.0
Blood/body fluid	20	0.9
Bloody solution	9	0.4
Body tissue	1,016	48.1
Other	6	0.3
Unknown	18	0.9
Missing	241	11.4
Occupational group of BBF exposed		
Attending physician	580	27.4
Anesthesiologist	37	1.8
Certified registered nurse anesthetist	136	6.4
Fellow/resident/student	846	40.0
Scrub nurse	263	12.4
Circulator nurse	84	4.0
Operating room/surgical technician	160	7.6
Other technician	7	0.3
Missing	0	0.0

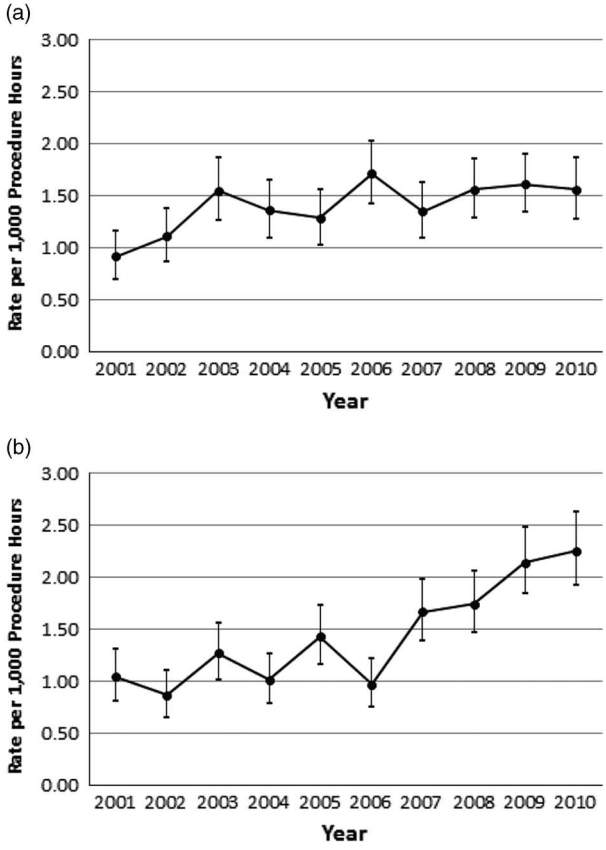

FIGURE 1. Rates of blood and body fluid exposures per 1,000 surgical procedure hours by year, with 95% CI error bars. *A*, for suture needles; *B*, for non–suture needle devices.

https://doi.org/10.1017/ice.2015.233 Published online by Cambridge University Press

TABLE 3. Poisson Regression Model Results for Percutaneous Blood and Body Fluid (BBF) Exposures: Models Stratified by Device Type

	Model 1: suture needle–related BBF exposures		Model 2: non–suture needle–related BBF exposures	
Risk factor	**Adjusted rate ratio[a]**	**95% CI**	**Adjusted rate ratio[a]**	**95% CI**
Shift of procedure start				
First shift: 07:00–14:59	1	(reference)	1	(reference)
Second shift: 15:00–22:59	1.07	(0.84–1.36)	0.98	(0.76–1.24)
Third shift: 23:00–06:59	0.82	(0.59–1.12)	0.96	(0.72–1.28)
Estimated patient blood loss				
None reported	1	(reference)	1	(reference)
1–500 cc	1.28	(1.09–1.51)	0.98	(0.83–1.14)
501–1,000 cc	1.86	(1.48–2.36)	1.56	(1.23–1.98)
>1,000 cc	2.58[b]	(1.97–3.36)	1.64[b]	(1.22–2.20)
Urgency of surgical case[c]				
Elective	1	(reference)	1	(reference)
Emergency: level 1	1.48	(1.06–2.06)	1.26	(0.86–1.83)
Emergency: levels 2–4	0.96	(0.73–1.26)	1.39	(1.10–1.76)
Emergency: level 5	1.00	(0.66–1.52)	1.28[d]	(0.89–1.84)
Procedure duration				
<2 hours	1	(reference)	1	(reference)
2 to <4 hours	1.41	(1.17–1.71)	1.14	(0.96–1.35)
4 to <6 hours	1.21	(0.95–1.53)	1.06	(0.85–1.32)
≥6 hours	1.22[e]	(0.93–1.60)	0.95	(0.73–1.23)
Number of personnel ever in surgical field				
1–7	1	(reference)	1	(reference)
8–14	1.49	(1.19–1.86)	1.07	(0.89–1.29)
≥15	2.31[b]	(1.61–3.29)	1.56[d]	(1.11–2.20)
Surgical service				
General surgery	1	(reference)	1	(reference)
Ophthalmology	0.74	(0.54–1.03)	1.34	(1.02–1.77)
Dental	0.36	(0.08–1.46)	0.81	(0.30–2.21)
Obstetrics/gynecology	2.06	(1.67–2.54)	1.04	(0.76–1.41)
Cardiac surgery	1.21	(0.93–1.56)	1.53	(1.16–1.99)
Neurosurgery	0.53	(0.40–0.70)	1.10	(0.85–1.42)
Ear, nose, and throat	1.39	(1.03–1.87)	1.71	(1.25–2.48)
Orthopedics	0.61	(0.50–0.75)	1.49	(1.22–1.82)
Plastic surgery	0.92	(0.67–1.25)	1.87	(1.41–2.48)
Pediatrics and subspecialties	1.55	(1.05–2.28)	0.85	(0.49–1.47)
Thoracic surgery	0.54	(0.36–0.82)	1.15	(0.82–1.63)
Urology	0.80[b]	(0.61–1.04)	1.09[d]	(0.81–1.45)

[a]Model is also adjusted for calendar year (not shown).
[b]Likelihood ratio test *P* values for class of indicator variables: <.001.
[c]To model the effect of urgency of the surgical case, levels 2, 3, and 4 were grouped together since statistical power did not allow for analysis of these levels separately.
[d]Likelihood ratio test *P* values for class of indicator variables: <.05.
[e]Likelihood ratio test *P* values for class of indicator variables: <.01.

contrasting elective procedures with all nonelective procedures (regardless of level) produced a rate ratio of 1.26 (95% CI, 1.04–1.53). Rate ratios for non–suture needle–related BBF exposures varied by surgical service; ophthalmology, cardiac, otolaryngology, orthopedics, and plastic surgery all had elevated rate ratios compared with general surgery. Also, blood loss, number of personnel in the field, and surgical service were all significantly associated with risk of BBF exposures due to non–suture needle devices. Exposure rates due to these devices did not vary across shift in the adjusted model.

DISCUSSION

During the 2001–2010 study period, 49% of BBF exposures that happened during surgical procedures in the OR were associated with the use of suture needles. Another report done at a teaching hospital showed nearly identical results, reporting that 50% of OR BBF exposures involved suture needles.[16] Approximately 28% of all BBF exposures in our study occurred to attending physicians/surgeons. This is similar to results reported by Jagger et al[8] that showed that residents and

https://doi.org/10.1017/ice.2015.233 Published online by Cambridge University Press

attending physicians accounted for 36% and 28% of exposures, respectively, and a French study that observed approximately 35% of BBF exposures occurred among surgeons.[16]

Consistent with our results, previous studies have shown procedure duration and estimated blood loss to be risk factors[13–15,18]; at least 1 prior study found an association with number of personnel in the surgical field.[15] Also, another prior study has demonstrated differences in BBF exposures rates across surgical services.[32]

Although the lack of association between shift and BBF exposures may be surprising, this finding is consistent with 1 study that examined all BBF exposures at a university hospital and found no association with time of day. However, in that study exposures were not limited to percutaneous exposures and the setting was not restricted to the OR.[33]

The device-stratified results show differing effects of procedure duration by device categories. Procedure duration was found to be associated with exposures involving suture needles but not with those involving all other device types. Because length of procedure may be correlated with complexity and the greater opportunity for using various devices, this was a rather unexpected finding. Regarding suture needles, the association does not show a steady rise in risk with procedure duration. Rather, in the adjusted model, the highest risk appears in procedures lasting 2 to 4 hours in duration. It is possible that this unexpected pattern is due to the inclusion of estimated blood loss and number of personnel in the surgical field, which may reflect procedure complexity, and the amount of suturing required, as well as duration. Greater complexity is a previously observed risk factor.[26]

It is possible that blood loss is modestly correlated with the degree of suturing required during a procedure and that this association represents exposure to the suturing task. It is also possible that blood loss represents confounding by complexity. Risk of suture needle–related exposures also trended upward across the number of personnel in the surgical field. This could represent greater procedure complexity or it may suggest that the physical crowding of the surgical field increases the risk of exposures involving suture needles.

Because 1 study found that emergency procedures had greater risk of exposure than scheduled operations,[18] we expected level 1 ("stat") urgency of the procedure would be associated with elevated risk of BBF exposure compared with elective procedures and those of lesser urgency. Emergency level 1 procedures had a higher level risk of suture needle exposures compared with all other emergency levels. When case urgency was grouped by elective vs nonelective cases, nonelective cases showed an elevated risk of BBF exposure involving devices other than suture needles. However, the pattern of rates across urgency categories differed by device types.

Risk of BBF exposures varied significantly among surgical services. This was true of both suture needle–related events and of events related to other device types. However, there were differences in the pattern of risk among specialties by device type. Obstetrics/gynecology, pediatrics and subspecialties, and ophthalmology all had significantly elevated rates of suture needle–related events compared with the general surgery referent group. These results may reflect more suturing performed in these services. However, obstetrics/gynecology, pediatrics and subspecialties, and ophthalmology again had significantly elevated rates of non–suture needle–related events as well as rates of events associated with suture needles. Although there are other possible explanations, the elevated risk of both kinds of events in these 3 surgical specialties suggests the possibility of better reporting in these groups. The cardiac and the orthopedic specialties were also found to have elevated risk of non–suture needle–related events. The elevated risk observed for these specialties may be due to the more frequent use of certain devices.

The increase in rates of BBF exposures over time was statistically significant for each device stratum. However, the meaning of this is not clear. It is possible that procedures are becoming more dangerous, but it is also possible that efforts to promote safety interventions and to encourage reporting of events may be responsible for this observed increase across the study period.

A major strength of this study was the availability of a very large number of surgical procedures and reported BBF exposures. The ability to match BBF exposure events to surgical procedures enabled an analysis of procedure characteristics; access to procedure duration allowed us to examine rates of exposures. The low rate of missing values of the study variables is also a strength of this study. The large number of BBF exposures included provided considerable power even when stratifying by device type.

A limitation of this study is its use of self-reported BBF exposures, as these events are gathered when surgery department personnel report their exposures to employee health staff. The actual number of exposures occurring in this workplace is undoubtedly higher than reported here. Some of the findings reported here may be due in part to differential reporting among occupations[4,34] and surgical services.[35] However, 1 study recently suggested the importance of setting, noting that dermatologists working in academic settings may report exposures at higher rates than those working in solo or group practice contexts.[36] Reporting at this academic institution, therefore, might be better than in other settings.

The device-stratified analysis demonstrated commonalities and differences in the associations between properties of procedures and the risk of BBF exposure. However, because this study took place in a single institution, future research is needed to confirm whether such differences exist in other settings to understand how risk factors might influence BBF exposures involving different devices. Future studies, if large enough, should also consider conducting analyses stratified by surgical specialty.

These findings suggest that future studies of BBF exposures in the OR consider examining events related to suture needles separately from those associated with other surgical instruments. Differences by surgical specialty might also be considered if statistical power allowed.

https://doi.org/10.1017/ice.2015.233 Published online by Cambridge University Press

Intervention measures were implemented during the study period, including the promotion of double-gloving and use of blunt suture needles, and a policy requiring the hands-free transfer of sharps, all of which were found to be the most proven measures of prevention in a recent literature review by DeGirolamo et al.[37] In addition, these measures have been recommended by the American College of Surgeons[38] and the Association of Perioperative Registered Nurses,[39] as well as the National Institute for Occupational Safety and Health.[40] Nonetheless, results show exposure rates of both suture needle and non–suture needle–related BBF exposures increased steadily over the study period.

It is not clear whether this increase is due to a greater frequency of BBF exposure events or an increase in reporting because the reporting of events at the study site had been repeatedly encouraged during the study period and in conjunction with the intervention measures. It is possible that the higher increase in exposure rates over time for events involving devices other than suture needles reflects an increase in the complexity or multitude of the surgical instruments, the procedures in which they are being used, or both. Such changes in the OR might call for evolving hazard prevention measures.

Regardless of what might be driving this increase in BBF exposures in the surgical theater, this finding is consistent with a recent study of 87 hospitals in the United States reported by Jagger et al.[7] The challenge of improving safety during surgical procedures, therefore, remains widespread and may require novel approaches centered on certain devices, surgical departments, or properties of surgical procedures.

ACKNOWLEDGMENTS

Financial support. National Institute for Occupational Safety and Health (grant 7K01OH009657).

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

Address correspondence to Douglas J. Myers, ScD, West Virginia University, Occupational and Environmental Health Sciences Department, 1 Medical Center Drive, PO Box 6190, Morgantown, WV 26506 (djmyers@hsc.wvu.edu).

REFERENCES

1. Beekmann SE, Henderson DK. Protection of healthcare workers from bloodborne pathogens. *Curr Opin Infect Dis* 2005;18:331–336.
2. Laramie AK, Pun VC, Fang SC, Kriebel D, Davis L. Sharps injuries among employees of acute care hospitals in Massachusetts, 2002–2007. *Infect Control Hosp Epidemiol* 2011;32:538–544.
3. Babcock HM, Fraser V. Differences in percutaneous injury patterns in a multi-hospital system. *Infect Control Hosp Epidemiol* 2003;24:731–736.
4. Doebbeling BN, Vaughn TE, McCoy KD, et al. Percutaneous injury, blood exposure, and adherence to standard precautions: are hospital-based health care providers still at risk? *Clin Infect Dis* 2003;37:1006–1013.
5. Dement JM, Epling C, Ostbye T, Pompeii LA, Hunt DL. Blood and body fluid exposure risks among health care workers: results from the Duke Health and Safety Surveillance System. *Am J Ind Med* 2004;46:637–648.
6. Bakaeen F, Awad S, Albo D, et al. Epidemiology of exposure to blood borne pathogens on a surgical service. *Am J Surg* 2006;192: e18–e21.
7. Jagger J, Berguer R, Phillips EK, Parker G, Gomaa AE. Increase in sharps injuries in surgical settings versus nonsurgical settings after passage of national needlestick legislation. *AORNJ* 2011;93:322–330.
8. Jagger J, Bentley M, Tereskerz P. A study of patterns and prevention of blood exposures in OR personnel. *AORNJ* 1998;67: 979–981; 983–984, 986–987 passim.
9. Makary MA, Al-Attar A, Holzmueller CG, et al. Needlestick injuries among surgeons in training. *N Engl J Med* 2007;356: 2693–2699.
10. McCormick RD, Meisch MG, Ircink FG, Maki DG. Epidemiology of hospital sharps injuries: a 14-year prospective study in the pre-AIDS and AIDS eras. *Am J Med* 1991;91:301S–307S.
11. Radecki S, Abbott A, Eloi L. Occupational human immunodeficiency virus exposure among residents and medical students: an analysis of 5-year follow-up data. *Arch Intern Med* 2000;160:3107–3111.
12. White MC, Lynch P. Blood contacts in the operating room after hospital-specific data analysis and action. *Am J Infect Control* 1997;25:209–214.
13. Gerberding JL, Littell C, Tarkington A, Brown A, Schecter WP. Risk of exposure of surgical personnel to patients' blood during surgery at San Francisco General Hospital. *N Engl J Med* 1990;322:1788–1793.
14. Panlilio AL, Foy DR, Edwards JR, et al. Blood contacts during surgical procedures. *JAMA* 1991;265:1533–1537.
15. Quebbeman EJ, Telford GL, Hubbard S, et al. Risk of blood contamination and injury to operating room personnel. *Ann Surg* 1991;214:614–620.
16. Tarantola A, Golliot F, L'Heriteau F, et al. Assessment of preventive measures for accidental blood exposure in operating theaters: a survey of 20 hospitals in Northern France. *Am J Infect Control* 2006;34:376–382.
17. Tokars JI, Bell DM, Culver DH, et al. Percutaneous injuries during surgical procedures. *JAMA* 1992;267:2899–2904.
18. White MC, Lynch P. Blood contact and exposures among operating room personnel: a multicenter study. *Am J Infect Control* 1993;21:243–248.
19. Florman S, Burgdorf M, Finigan K, Slakey D, Hewitt R, Nichols RL. Efficacy of double gloving with an intrinsic indicator system. *Surg Infect* 2005;6:385–395.
20. Vaughn TE, McCoy KD, Beekmann SE, Woolson RE, Torner JC, Doebbeling BN. Factors promoting consistent adherence to safe needle precautions among hospital workers. *Infect Control Hosp Epidemiol* 2004;25:548–555.
21. Sohn S, Eagan J, Sepkowitz KA, Zuccotti G. Effect of implementing safety-engineered devices on percutaneous injury epidemiology. *Infect Control Hosp Epidemiol* 2004;25:536–542.
22. Centers for Disease Control and Prevention. Evaluation of blunt suture needles in preventing percutaneous injuries among healthcare workers during gynecologic surgical procedures–New York City, March 1993-June 1994. *MMWR Morb Mortal Wkly Rep* 1997;46:25–29.
23. Stafford M, Uthayakumar S, Falder S, Thomas P, Jolly M, Smith JR. Techniques for reducing needlestick injury in surgical practice. *Infect Control Hosp Epidemiol* 1994;15:350.

24. Vose JG, McAdara-Berkowitz J. Reducing scalpel injuries in the operating room. *AORNJ* 2009;90:867–872.
25. Goob TC, Yamada SM, Newman RE, Cashman TM. Bloodborne exposures at a United States Army Medical Center. *Appl Occup Environ Hyg* 1999;14:20–25.
26. Puro V, De Carli G, Petrosillo N, Ippolito G. Risk of exposure to bloodborne infection for Italian healthcare workers, by job category and work area. Studio Italiano Rischio Occupazionale da HIV Group. *Infect Control Hosp Epidemiol* 2001;22:206–210.
27. Venier AG, Vincent A, L'Heriteau F, et al. Surveillance of occupational blood and body fluid exposures among French healthcare workers in 2004. *Infect Control Hosp Epidemiol* 2007;28:1196–1201.
28. Myers DJ, Epling C, Dement J, Hunt D. Risk of sharp device-related blood and body fluid exposure in operating rooms. *Infect Control Hosp Epidemiol* 2008;29:1139–1148.
29. Dement JM, Pompeii LA, Ostbye T, et al. An integrated comprehensive occupational surveillance system for health care workers. *Am J Ind Med* 2004;45:528–538.
30. Loomis D, Richardson DB, Elliott L. Poisson regression analysis of ungrouped data. *Occup Environ Med* 2005;62:325–329.
31. StataCorp. Stata Statistical Software: Release 11. College Station, TX: StataCorp, 2009.
32. Tokars JI, Culver DH, Mendelson MH, et al. Skin and mucous membrane contacts with blood during surgical procedures: risk and prevention. *Infect Control Hosp Epidemiol* 1995;16: 703–711.
33. Macias DJ, Hafner J, Brillman JC, Tandberg D. Effect of time of day and duration into shift on hazardous exposures to biological fluids. *Acad Emerg Med* 1996;3:605–610.
34. Voide C, Darling KE, Kenfak-Foguena A, Erard V, Cavassini M, Lazor-Blanchet C. Underreporting of needlestick and sharps injuries among healthcare workers in a Swiss university hospital. *Swiss Med Wkly* 2012;142:w13523.
35. Au E, Gossage JA, Bailey SR. The reporting of needlestick injuries sustained in theatre by surgeons: are we under-reporting? *J Hosp Infect* 2008;70:66–70.
36. Donnelly AF, Chang YH, Nemeth-Ochoa SA. Sharps injuries and reporting practices of U.S. dermatologists. *Dermatol Surg* 2013;39:1813–1821.
37. DeGirolamo KM, Courtemanche DJ, Hill WD, Kennedy A, Skarsgard ED. Use of safety scalpels and other safety practices to reduce sharps injury in the operating room: what is the evidence? *Can J Surg* 2013;56:263–269.
38. Berguer R, Heller PJ. Preventing sharps injuries in the operating room. *J Am Coll Surg* 2004;199:462–467.
39. Association of Perioperative Regiestered Nurses. AORN guidance statement: sharps injury prevention in the perioperative setting. *AORNJ* 2005;81:662–665.
40. National Institute for Occupational Safety and Health. Use of blunt-tip suture needles to decrease percutaneous injuries to surgical personnel. CDC website. http://www.cdc.gov/niosh/docs/2008-101/. Published 2007. Updated June 6, 2014. Accessed September 16, 2015.

https://doi.org/10.1017/ice.2015.233 Published online by Cambridge University Press