Personal Protective Equipment Use and Hazardous Drug Spills Among Ambulatory Oncology Nurses

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Purpose/Objectives: To examine patterns and organizational correlates of personal protective equipment (PPE) use and hazardous drug spills.

Design: Cross-sectional mailed survey.

Setting: Ambulatory practices in California, Georgia, and Michigan.

Sample: 252 Oncology Nursing Society members who administer hazardous drugs.

Methods: Bivariate and multivariable regression analyses.

Main Research Variables: Outcomes were PPE use and hazardous drug spills. Covariates included nursing workloads, nurses' practice environments, and barriers to PPE use.

Findings: Twenty-six percent reported a recent drug spill, and 90% wore only one pair of chemotherapy-tested gloves. Increased PPE use was associated with increased nurse participation in practice affairs, nonprivate ownership, increased nursing workloads, and fewer barriers to PPE use. Spills were associated with significantly less favorable manager leadership and support and higher workloads.

Conclusions: Drug spills occur often in ambulatory settings. PPE use remains low, and barriers to PPE use persist. Higher workloads are associated with more drug spills.

Implications for Nursing: Managers should monitor and correct aberrant workloads and ensure that PPE is available and that staff are trained.

About 8 million healthcare workers are potentially exposed to hazardous drugs each year in the United States (Connor & McDiarmid, 2006; Randolph, 2012). Oncology nurses prepare and administer substantial volumes of antineoplastic drugs; roughly 18 million doses are administered to adults annually in the United States (Cherry, Woodwell, & Rechtsteiner, 2007). Potentially harmful urinary and blood metabolites have been detected in nurses who handle these drugs (Connor et al., 2010). Adverse health effects from exposures include acute issues (skin rashes, eye irritation, nausea), long-term reproductive issues (infertility, spontaneous abortions, congenital anomalies), and possible cancers (National Institute for Occupational Safety and Health [NIOSH], 2004; Occupational Safety and Health Administration, 1999).

Despite more than 30 years of efforts to improve personal protective equipment (PPE) use and safe-handling guidelines, recent studies have documented work surface contamination and dermal, eye, and inhalation exposure among oncology nurses who report hazardous drug spills (Friese, Himes-Ferris, Frasier, McCullagh, & Griggs, 2011; Kopp, Schierl, & Nowak, 2012). NIOSH (2004) reported workplace hazardous drug exposure as a persistent problem among healthcare workers. The use of chemotherapy-tested gloves, single-use disposable gowns, respirators or masks, eye protection, and closed-system transfer

devices are recommended to protect against unintentional exposures (Valanis, Vollmer, Labuhn, Glass, & Corelle, 1992). However, studies evaluating nurses' safe-handling performances have highlighted frequent barriers to PPE use. Despite increased availability of recommended PPE in workplaces, nurses may not use these devices because of either attitudes toward PPE or lack of available equipment (Boiano, Steege, & Sweeney, 2014; Martin & Larson, 2003; Polovich & Clark, 2012).

The Oncology Nursing Society and the American Society of Clinical Oncology recommend consistent PPE use to reduce drug spills and subsequent exposure (Jacobson et al., 2009), although organizational factors that influence PPE use and drug exposure are unclear. A 2012 survey of nurses found that lower workloads, nurse participation in decision making, adequate staffing, and a two-nurse order verification system were associated with a lower incidence of skin or eye exposure to hazardous drugs (Friese et al., 2011). Additional studies have shown that fewer reported barriers to PPE use and frequent performance of safety-promoting behaviors were associated with improved handling of hazardous drugs (Friese, McArdle, et al., 2015; Polovich & Clark, 2012). However, few studies have examined organizational factors and barriers related to PPE use across diverse ambulatory settings. A better understanding of the mechanisms and processes by which organizations protect oncology nurses from potential hazardous drug exposure is necessary to inform interventions.

Nurse reports of hazardous drug spills provide insight into high-risk adverse events. The authors of the current study used a cross-sectional, multistate survey of oncology nurses to identify associations between (a) organizational factors and reported barriers and (b) two key outcomes, PPE use and self-reported drug spills. The results can inform policymakers, clinical administrators, and clinicians on how to improve PPE use and reduce potential exposures and harm among healthcare workers.

Methods

In 2014, members of the Oncology Nursing Society in Michigan, Georgia, or California (N = 654) who held part- or full-time employment status in ambulatory oncology settings were invited to respond to a mailed questionnaire. Using Dillman's total design method to maximize response rates (Dillman, Smyth, & Christian, 2008), the authors of the current study personalized cover letters, provided $40 cash incentives to participants, and sent as many as three monthly reminders to nonresponders.

The questionnaire included items relating to PPE use and hazardous drug spills, key covariates of organizational structure, perceived barriers to PPE use, and personal and practice factors. Measures were selected in congruence with Donabedian's Quality of Care Model (Donabedian, 2005) and extant frameworks that examine PPE use by workers (McCullagh, Ronis, & Lusk, 2010).

The study examined two primary outcomes: hazardous drug spills and self-reported PPE use within the past six months (from February to September 2014) using multiple scales. The Revised Hazardous Drug Handling Questionnaire measures the frequency of PPE use among oncology nurses when preparing or administering hazardous drugs (Martin & Larson, 2003; Polovich & Clark, 2012). The scale measures the use of chemotherapy-tested gloves, the double-gloving technique, single-use disposable gowns, eye protection, respirators/masks, and closed-system transfer devices on a six-point Likert-type scale ranging from 0 (never) to 5 (always). The PPE outcome was derived from a mean score of the six items. The second outcome—reported hazardous drug spills—was treated as a binary (yes or no) outcome; nurses were asked if they had experienced a spill, drop, or leak of hazardous drugs greater than 5 ml within the past six months.

The Safety Organizing Scale measures collective behaviors performed by employees in high-reliability

TABLE 1. Participant Characteristics

	Analytic Sample (N = 252)		Survey Sample (N = 437)	
Characteristic	**$\bar{X}$**	**SD**	**$\bar{X}$**	**SD**
Age (years)	51	10.5	50	10.5
Years in oncology	13.1	9.5	14	9.5
Nurse workload (patients per shift)	8.6	7.6	9.9	18.2
Characteristic	**n**	**%**	**n**	**%**
Practice ownership				
Private	103	41	153	35
Nonprivate	142	56	275	63
Not provided	7	3	9	2
States				
California	157	62	250	57
Georgia	43	17	79	18
Michigan	52	21	108	25
Education				
Diploma or associate degree	128	51	182	42
Bachelor's degree or higher	121	49	248	58
Not provided	3	1	7	1

Note. Because of rounding, percentages may not total 100.

TABLE 2. Organizational Factors and Personal Protective Equipment Use[a]

Variable	Parameter Estimate	95% CI	p
Nurse participation in practice affairs	0.25	[0.1, 0.41]	0.001
Collegial nurse–physician relations	–0.19	[–0.35, –0.03]	0.02
Barriers to protective equipment use[b]	0.65	[0.36, 0.93]	< 0.001
Nursing workloads	0.03	[0.01, 0.04]	< 0.01
Nonprivate practice ownership	0.37	[0.1, 0.64]	< 0.01

[a]Multivariate linear regression analysis using generalized estimating equations to account for clustering of nurses within practices
[b]Barriers to Protective Equipment Use scale is reverse scored (higher score reflects fewer barriers).
CI—confidence interval

organizations (e.g., nuclear power plants) to mitigate high-stakes operational failures (Vogus & Sutcliffe, 2007). The nine-item scale measures the present safety performance and modifiable actions of clinicians. The frequency of performing safety behaviors in the workplace is scored on a seven-point Likert-type scale ranging from 1 (not at all) to 7 (a very great extent). This scale has demonstrated high internal reliability and validity (Vogus & Sutcliffe, 2007; Wilson, 2012).

Nursing practice environments are workplace features that enable nurses to deliver high-quality care (Lake & Friese, 2006). Environments were measured using the Practice Environment Scale of the Nursing Work Index (PES-NWI) revised for ambulatory oncology settings. The revised PES-NWI items reflect the presence of six key work features: (a) collegial nurse–physician relations; (b) participation in practice affairs; (c) managers' ability, leadership, and support; (d) staffing and resource adequacy; (e) supportive relations with medical assistants; and (f) foundations for quality care. A total of 23 items are scored on a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores reflect more positive environments. Each subscale was derived from item means. Subscales have documented validity and reliability in prior studies (Cronbach alphas for internal consistency ranged from 0.8–0.9) (Shang, Friese, Wu, & Aiken, 2013).

Barriers to wearing PPE were measured with 13 items in Geer's Dermal Exposure Survey (Geer, Curbow, Anna, Lees, & Buckley, 2006). Nurses scored items on a five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree), and the mean across all 13 items was used in analyses. In addition, nurses reported their average workloads (average number of patients cared for during the last shift), oncology practice ownership (private versus nonprivate), and demographics (years of nursing experience, oncology certification, and education level).

Statistical analyses were performed with SAS®, version 9.4. Relationships between the two outcome variables and dependent variables were explored with bivariate analyses, including independent sample t-tests and chi-square tests. Based on the distribution of the outcomes, linear regression models were used to estimate PPE use, with generalized estimating equations specified to account for the clustering of nurses within practices. To examine factors associated with hazardous drug spills, multivariable logistic regression models were estimated with generalized estimating equations. In addition, to achieve parsimonious models, backward selection procedures were used to remove variables that did not reach significance ($p < 0.3$). Final models retained main effect covariates that reached significance ($p < 0.05$). Interaction terms between barriers to PPE and organizational factors were also tested (Knol & VanderWeele, 2012).

Results

In total, 437 nurses completed surveys (67% response). Participant characteristics are shown in Table 1. Most participants were women (97%), aged 43 years or older (79%), had at least six years of oncology experience (75%), and worked in outpatient oncology settings (96%). Nurses worked in 132 oncology facilities in California (62% of total), Michigan (21%), and Georgia (17%), with 1–12 nurses employed at each facility. Slightly more nurses worked in public, nonprofit, or government-owned practices (56%) than privately owned practices (41%). When asked the average direct care workload during their last work shift, 72% of respondents reported providing care to five–nine patients, on average. A few nurses (1%–9%) did not provide demographic data. The final analytical sample (N = 252) excluded 23 respondents who did not meet study criteria and 192 nurses whose routine work did not include preparing or administering hazardous drugs. The authors did not observe significant differences among study variables between the analytic sample and excluded participants.

The sample mean for the PPE-use score was 2.4 (SD = 1) out of a maximum possible score of 5. In particular, 224 respondents (90%) wore only one pair of chemotherapy-tested gloves at least 75% of the time during

routine administration and preparation activities. However, 22%–44% of the nurses reported never using other recommended techniques or PPE such as gowns, eye protection, double gloving, and closed-system transfer devices while handling hazardous drugs.

Table 2 shows the results of PPE use from the multivariable linear regression analysis, which were adjusted for nonprofit ownership and nursing workloads. After backward selection procedures, five variables were retained in the model. Increased nurse participation in practice affairs, fewer barriers to PPE use, nonprofit ownership, and higher workloads were associated with significantly higher scores on the PPE-use scale. Collegial nurse–physician relationships were associated with significantly lower scores.

Among nurses who routinely prepared or administered hazardous drugs, 51 reported a spill, drop, or leak of hazardous drugs of 5 ml or more within the past six months. Five exposed individuals reported skin contact or eye contact with hazardous drugs, and four participants reported acute health problems including coughing, nose burning sensations, and headaches. When asked if nurses were concerned about the spill, 25 of the respondents expressed that they were somewhat or strongly concerned about the spill. During the spill response, nurses reported wearing the following PPE: 41 used gowns, 29 used chemotherapy-tested gloves, 20 wore double gloves, 28 wore respirators/masks, and 23 wore eye protection. Spills occurred during patient-related tasks (n = 8), prepping/spiking IV bags (n = 9), starting/during infusion (n = 25), storing/disposing of drugs (n = 8), and equipment malfunctions (n = 2). Among 17 nurses who used a closed-system transfer device during a spill, 10 reported a device malfunction.

Table 3 compares organizational factors for those who did and did not report spills. Nurses who reported hazardous drug spills within the past six months had significantly lower Safety Organizing Scale scores, lower scores on the two PES-NWI subscales (nurse participation in practice affairs and manager ability, leadership, and support), and more barriers to PPE use.

After backward selection procedures, three variables were retained in the logistic regression model that estimated the odds of a hazardous drug spill report. After adjusting for barriers to PPE use, nurses who reported favorable nurse manager ability, leadership, and support were significantly less likely to report hazardous drug spills (odds ratio [OR] = 0.68, 95% confidence interval [CI] [0.47, 0.98], p = 0.04). Nurses who reported fewer barriers to PPE use were significantly less likely to report spills (OR = 0.65, 95 CI [0.35, 1.12], p = 0.17). As nursing workloads increased by one patient, the odds of hazardous drug spills increased by 3% (OR = 1.03, 95% CI [1.01, 1.06], p = 0.01).

Discussion

Recommendations for safe-handling practices of hazardous drug have remained relatively consistent through the years; however, suboptimal PPE use and hazardous drug spills among oncology nurses are persistent problems. PPE use has increased overall, as reflected in prior work that documents increased glove use from a historic low of 49% in 1987 to 90% during the current study (Boiano et al., 2014; NIOSH, 2004). However, not all recommended types of PPE are accepted, available, or accessible in oncology workplaces. Other recommended types of PPE and procedures, including single-use disposable gowns, double-gloving practices, eye protection, respirators, and closed-system transfer devices, are used less frequently outside of hospital

TABLE 3. Organizational Factors and Nurse-Reported Hazardous Drug Spills

	Spill Reported (N = 51)		Spill Not Reported (N = 199)		
Variable	**$\bar{X}$**	**SD**	**$\bar{X}$**	**SD**	**p[a]**
Safety Organizing Scale	5.2	1	5.6	1	0.03
Practice Environment Scale of the Nursing Work Index					
Nurse participation in practice affairs	2.8	0.9	3.1	0.9	0.05
Nurse manager ability, leadership, support	3.3	1	3.6	0.9	0.04
Collegial nurse–physician relations	3.8	0.9	4	0.8	0.15
Staffing and resource adequacy	3.3	1	3.4	1	0.5
Nursing foundations for quality of care	4.1	0.4	4.3	0.6	0.09
Supportive medical assistant relations	3.6	1	3.9	0.87	0.15
Geer's Dermal Exposure Survey					
Barriers to protective equipment use	3	0.5	3.3	0.5	0.03
Other					
Nursing workload	10	12	8	6	0.29
Years of oncology experience	13	9.6	13	9.5	0.66
Variable	**n**	**%**	**n**	**%**	**p[b]**
Ownership					
Nonprofit	27	53	114	57	0.41
Private, for-profit	24	47	78	39	–
Not provided	–	–	7	4	–

[a] P values were obtained from independent sample t-tests.
[b] P value was obtained from likelihood-ratio chi-square tests.

Knowledge Translation

- Workloads are an important factor to consider in reducing hazardous drug exposure.
- Nurses reported substantial barriers to exposure prevention, including absence of equipment and lack of training.
- Educational interventions are needed to improve the use of personal protective equipment to reduce hazardous drug exposure.

inpatient settings. In the current study, 22%–44% of nurses reported never using those items. This finding underscores persistent organizational challenges to improve PPE access and adoption.

Consistent with prior studies, the questionnaire findings suggest that improved nursing participation in decision making and fewer barriers in the practice can enhance PPE use (Boiano et al., 2014; Martin & Larson, 2003; Polovich & Clark, 2012). The authors of the current study observed a counterintuitive relationship between collegial nurse–physician relationships and lower PPE use. Perhaps practices with positive nurse–physician relationships have less formal work environments and lack standardized processes for routine work. Interaction effects among practice ownership, practice size, and nurse–physician relationships may have existed, which could not have been tested in the current study. Efforts to improve PPE use in the workplace include engaging nurses in selecting appropriate PPE for purchase, ensuring open communication among nurses and facility administrators, and providing opportunities for nurses to participate in decision making. After adjusting for other factors, perceived barriers to PPE use, including infrequent PPE use by nurse peers, PPE use making nurses too warm, and unavailable PPE, remain the most significant factors associated with low PPE use (Sadoh, Fawole, Sadoh, Oladimeji, & Sotiloye, 2006).

The current study found higher PPE use among nurses employed by university, public, and government practices. As practice ownership cannot likely be modified, the study findings underscore the need to improve individual adherence through modifiable administrative controls (e.g., commitments to safety culture, improved nurse practice environments, thoughtful attention to nurse workloads, deployment of engineering controls).

The findings showed that lower nursing workloads and more favorable manager support are correlated with fewer reported drug spills. Hazardous drug spills occurred relatively frequently, which speaks to the need for increased management attention. Nurses documented spills related to infusion, patient handling, medical device malfunction, and storage and disposal. In addition, engineering controls did not reliably operate as designed.

Limitations

The internal reliability of the dependent variable—the PPE-use scale—was lower in the current sample (0.61) than previously reported (Geer et al., 2006). The distribution of various PPE (included on the PPE-use scale) had a bimodal pattern; many respondents reported either using PPE very frequently or never. Other limitations included a varying number of respondents per practice (1–12 nurses) and missing data. Roughly a third of practices had only one nurse informant. These limitations are somewhat offset by the large sample size, high response rate, and geographic diversity.

Implications for Nursing Practice and Research

Three decades of study have failed to provide adequate attention to hazardous drug handling. The current study identifies the need for personal and organizational intervention. Employers need to ensure that workers are adequately protected through increased adherence to engineering (i.e., closed-system transfer devices), administrative (i.e., clinic-based policies and procedures on PPE use), and PPE control measures. Healthcare facilities managers may benefit from guidance on how to reduce the risk of hazardous drug exposure among employees, including facilitating clinician input on decisions and lower workloads and eliminating structural barriers to PPE use. The barriers identified in this study were used to design the intervention to improve PPE use in a multisite randomized clinical trial (Friese et al., 2015). Additional longitudinal studies are needed to test the efficacy and effectiveness of interventions designed at both individual and organizational levels.

Conclusion

Among oncology nurses who administer hazardous drugs, more frequent use of PPE was associated with higher nurse participation in practice affairs and nonprofit ownership. Inverse associations existed between PPE use and higher physician–nurse collaboration and patient workloads per shift. Self-reported hazardous drug spills occurred less often with increased performance of safety behaviors, more favorable perceptions of management, adequate staffing and resources, and lower barriers to PPE use. The high rate of spills and associated risk of exposure to hazardous drugs suggests that employers must increase their

efforts to protect workers through more effective engineering, administrative, and PPE controls.

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