Testing an Intervention to Decrease Healthcare Workers' Exposure to Antineoplastic Agents

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Purpose/Objectives: To develop and test a worksite intervention that protects healthcare workers who handle antineoplastic drugs from work-related exposures.

Design: Intervention study.

Setting: A university hospital in a large midwestern metropolitan area and its outpatient chemotherapy infusion clinic.

Sample: 163 staff (nurses, pharmacists, and pharmacy technicians) who work with antineoplastic agents.

Methods: A self-report survey measured workplace and individual factors to assess use of personal protective equipment (PPE). Wipe samples were tested for surface contamination. An intervention incorporating study findings and worker input was developed.

Main Research Variables: PPE use was the dependent variable, and the independent variables included knowledge of the hazard, perceived risk, perceived barriers, interpersonal influence, self-efficacy, conflict of interest, and workplace safety climate.

Findings: PPE use was lower than recommended and improved slightly postintervention. Self-efficacy and perceived risk increased on the post-test survey. Chemical residue was found in several areas. Awareness of safe-handling precautions improved postintervention. The unit where nurses worked was an important predictor of safety climate and PPE use on the pretest but less so following the intervention.

Conclusions: Involving staff in developing an intervention for safety ensures that changes made will be feasible. Units that implemented workflow changes had decreased contamination.

Implications for Nursing: Worksite analysis identifies specific targets for interventions to improve antineoplastic drug handling safety.

About 1.7 million Americans were expected to be diagnosed with cancer in 2016 (American Cancer Society, 2016). Chemotherapy drugs are often part of an effective treatment plan. Patients receiving chemotherapy are advised of potential adverse outcomes of treatment, such as the future risk of secondary cancers and negative reproductive outcomes (Deniz, O'Mahony, Ross, & Purushotham, 2003; Josting et al., 2003; Sherins & DeVita, 1973). For patients, the benefits of treatment outweigh the risks. Healthcare workers, such as nurses and pharmacists, are pivotal in patient care. Unfortunately, providing this care has the potential to put healthcare workers at risk of chemotherapy exposures. Previous studies have documented chemotherapy residues on countertops and floors in pharmacy, nursing, and patient care areas (Connor et al., 2010). Eight million healthcare workers are estimated to be exposed to chemotherapy annually, with pharmacists and nurses being among the groups with the highest incidence of exposure

(Connor et al., 2010; Polovich & Clark, 2012). Even a small exposure to antineoplastic drugs can cause adverse outcomes, including skin rashes, nausea, hair loss, abdominal pain, nasal sores, allergic reactions, skin or eye injury, and dizziness (Valanis, Vollmer, Labuhn, & Glass, 1993; Vioral & Kennihan, 2012). Healthcare workers incur exposure on a repeated basis and often for many years. Chronic effects linked with exposure include reproductive harm, such as delayed time to conception (Fransman et al., 2007), spontaneous abortion (Lawson et al., 2012), genotoxic changes (McDiarmid, Oliver, Roth, Rogers, & Escalante, 2010; Rekhadevi et al., 2007; Villarini et al., 2011), and cancers (Skov et al., 1992).

Safe-handling practices, such as the use of personal protective equipment (PPE) by staff, are known to reduce exposure and likelihood of health effects from chemotherapy (National Institute for Occupational Safety and Health [NIOSH], 2004). Federal guidelines for safe handling were first published by NIOSH in 1986 and updated in 2004 (NIOSH, 2004). Guidelines are also published by the Oncology Nursing Society (Polovich, 2011) and the American Society of Health-System Pharmacists (2006). Such guidelines recommend workers wear PPE (including double gloves, goggles, and protective gowns) for all activities associated with drug administration and disposal of all equipment used to administer drugs (NIOSH, 2004). However, these guidelines are only recommendations, and federal policies are lacking. There have been state-based laws passed to standardize hazardous drug safety practices in Washington in 2011 (Smith, 2011), in California in 2013 (California Legislative Information, 2013), and in North Carolina in 2014 (North Carolina General Assembly, 2014). The lack of consistency in state policies may lead to differences in healthcare workers' use of safe-handling precautions (Boiano, Steege, & Sweeney, 2014; Environmental Working Group, 2007). A positive workplace safety climate and a higher nurse-to-patient ratio can positively affect adoption of safe-handling practices (Friese, Himes-Ferris, Frasier, McCullagh, & Griggs, 2012; Polovich & Clark, 2012).

Quality improvement processes have been used in health care to improve patient safety (Langley et al., 2009). However, use of the quality improvement process to enhance chemotherapy safe handling has only recently been described in the literature. Hennessy and Dynan (2014) reported study findings from a program implemented to improve safe handling of chemotherapy at the Dana-Farber Cancer Institute. The program incorporated monitoring and reporting compliance on the use of PPE, as well as engaging staff in audit activities (Hennessy & Dynan, 2014).

The objectives of this study were to (a) determine key factors influencing exposure to antineoplastic agents for nurses and pharmacy staff, (b) determine if work surfaces were contaminated with antineoplastic drugs, and (c) develop and test a sustainable intervention to improve the safety of chemotherapy handling.

Methods

This study used a pre-/post-test design on an intervention to improve antineoplastic drug safe handling by staff who are potentially exposed. Nurses, pharmacists, and pharmacy technicians (N = 163) from four units (i.e., inpatient oncology, inpatient bone marrow transplantation, outpatient chemotherapy infusion center, and pharmacy) at a university hospital in a large midwestern metropolitan area participated. A self-report survey was administered combining questions about PPE use with questions based on a theoretical model used by Polovich and Clark (2012) to test predictor variables. The survey was offered online for three weeks in October 2014 (pretest) and three weeks in August 2015 (post-test). Survey respondents were entered into a drawing for a $50 gift card (one winner for each unit). Surface samples were collected one day prior to the survey release. An exposure assessment was conducted using area surface sampling to measure contamination before (pretest), during, and following (post-test) the intervention. The study was approved as exempt by the University of Minnesota Institutional Review Board and the hospital's nursing research council.

Environmental Assessment

An exposure assessment tool, the ChemoAlert™ Surface Contamination Kit (Bureau Veritas North America, 2013), was used for testing surfaces for contamination. This tool was developed for facilities to measure surface chemotherapy contamination in response to recommendations for periodic testing from NIOSH (2004) and a housekeeping standard recommendation (Lee, 2010). The number of swab strokes per wipe sample was standardized. The laboratory provided one sample blank as a control for each set of samples that was delivered to them to ensure accurate testing. A total of 27 locations were selected for surface wipe sampling for antineoplastic drug residue. Selection of the antineoplastic agents to be tested was made based on those agents with the highest volume of use, consistent with the approach used in similar studies (Connor et al., 2010). Sampling sites on each unit were selected based on workflow and the locations in which the selected drugs were most commonly used. The variety of job tasks associated with potential chemotherapy exposure (drug preparation, administration, disposal, and handling excreta) was also considered. An experienced industrial hygienist provided guidance on the planning and implementation of the exposure assessment and wipe sampling. The size of the test sites was from 100 cm^2 to 200 cm^2, based on the size of the surface. All locations were tested pre- and post-test, accounting for 62 unique antineoplastic drug-by-location combinations. When pretest samples were reported as positive, the hospital staff identified additional areas of concern that resulted in expanded testing. Twelve additional wipe samples were taken during the intervention (hereafter referred to as intervention samples).

Survey

Self-reported survey measures: Survey items were taken from instruments with established reliability and validity used in a study by Polovich and Clark (2012). The survey included items about personal factors, such as age, race, and years of experience.

Dependent or outcome variable: Use of safe-handling techniques was measured on a five-point scale with questions adapted from the Revised Hazardous Drug Handling Questionnaire (Polovich & Clark, 2012), which was based on federal guidelines for safe handling (NIOSH, 2004). Questions included items about availability and use of PPE during four categories of potential exposure: preparation, administration, disposal, and handling patient excreta. PPE use questions were scored from 5 (always use) to 0 (never use). Use of PPE was calculated as a score for each respondent based on their responses to the use of gloves, double gloves, gowns, whether or not they reused disposable gowns, and eye protection.

Independent variables: Predictor variables and their attributes are outlined in Table 1. All survey measures except knowledge of the hazard were adapted from Geer et al. (2007) and Gershon et al.

TABLE 1. Explanation of Predictor Variables for Intervention Survey

Predictor Variable	Description	Example Item	Number of Items	Response Options
Knowledge of the hazard	Address chemotherapy exposure routes and appropriate use of PPE.	"Chemotherapy can enter the body through breathing it in."	12	"True," "false," or "do not know"
Perceived barriers	Address the need for and efficacy of PPE, time for use, and other physical and emotional discomfort hindrances to wearing PPE.	"PPE makes it harder to get the job done."	12	Four-point scale from "strongly agree" to "strongly disagree"
Perceived conflict of interest	Address how PPE use might be affected by a workers' ability to protect themselves and provide patient care.	"Wearing PPE makes my patients worry."	6	Four-point scale from "strongly agree" to "strongly disagree"
Perceived risk	Address the seriousness of the occupational exposure for one's health, probability of current and future harm to oneself, and one's risk in relation to coworkers.	"Exposure to chemotherapy is a serious problem at my work."	7	Four-point scale from "strongly agree" to "strongly disagree"
Self-efficacy	Assess confidence in the use of PPE, the ability of PPE to protect, available resources, and managerial support during the handling of chemotherapy.	"I am confident that I can protect myself from chemotherapy exposure."	7	Four-point scale from "strongly agree" to "strongly disagree"
Workplace safety climate	Assess for accessibility of PPE, how safety is assessed by managers, training, the cleanliness of the workplace, coworker support, and safety policy.	"On my unit, reasonable steps are taken to minimize hazardous job tasks."	21	Five-point scale from "strongly agree" to "strongly disagree"
Interpersonal influence	Ask how often coworkers use PPE and how important the use of PPE is to coworkers.	"How often do your coworkers wear PPE when handling chemotherapy?"	6	Five-point scale from "never" to "usually" and four-point scale from "not at all important" to "very important," with additional option of "does not apply" for all

PPE—personal protective equipment

TABLE 2. Surface Contamination Results From Locations That Tested Above the LOD During the Study

Location	Antineoplastic Drug Tested	Pretest Results	Post-Test Results	Intervention Results
Outpatient pharmacy B/nursing infusion center				
Floor under laundry bin	Paclitaxel[a]	0.03 ng/cm²	0.13 ng/cm²	-
Patient chair armrest following paclitaxel infusion	Paclitaxel[a]	0.02 ng/cm²	< LOD	-
Nursing to pharmacy counter under bin return	Paclitaxel[a]	0.05 ng/cm²	< LOD	-
Inpatient oncology				
Nurses' station counter opposite charge (where chemotherapy is double-checked)	Ifosfamide[a]	0.06 ng/cm²	< LOD	-
Medication room: Refrigerated chemotherapy bin A–M	Etoposide[a]	< LOD	0.29 ng/cm²	-
Medication room: Refrigerated chemotherapy bin A–M	Ifosfamide[a]	< LOD	0.63 ng/cm²	–
Charge desk: Counter spot A	Ifosfamide[a]	-	-	0.008 ng/cm²
Bag of ifosfamide: Front	Ifosfamide[a]	-	-	34.4 ng/cm²
Bag of ifosfamide: Back	Ifosfamide[a]	-	-	9.42 ng/cm²
Inpatient bone marrow transplantation				
Patient side table	Cyclophosphamide[b]	0.008 ng/cm²	< LOD	-
Patient bathroom floor: Left	Cyclophosphamide[b]	-	-	0.18 ng/cm²
Patient bathroom floor: Right	Cyclophosphamide[b]	-	-	0.35 ng/cm²
Chemotherapy cart spot A	Cyclophosphamide[b]	-	-	0.12 ng/cm²

[a] LOD is 0.005 mcg/cm²
[b] LOD is 0.015 ng/cm²
LOD—limit of detection
Note. Post-test results were taken six months following the intervention.

(1995, 2007). Knowledge of the hazard was measured based on adaptation of items from the NIOSH survey of safe handling for workers, as well as the chemotherapy exposure knowledge scale (Polovich & Clark, 2012).

Pregnancy and alternative duty: Female respondents were asked whether or not they had been pregnant during their current job, and, if so, whether they sought alternative duty that did not include chemotherapy handling. If they had not been pregnant, they were asked if they would seek alternative duty if they became pregnant. These questions were pilot tested with nursing management. Men were asked to comment on why they felt a pregnant woman might choose to ask to be moved to another assignment.

Intervention

Management and staff were presented with the pretest results during staff and nurse council meetings. Small workgroups of nursing practice council members were formed to address areas of concern for each unit. Consistent with the quality improvement literature, small changes were made, including moving chemotherapy gowns from one location in a locked room to hallway closets outside patient rooms to increase an individual nurse's convenience and placing signs on the units reminding staff not to reuse disposable gowns. Changes were tested with brief surveys or qualitative interviews to address how staff felt the changes were effective (e.g., acceptable to staff, improving PPE use, decreasing the number of surfaces that tested positive for chemotherapy residue). Interventions on each unit were tested for effectiveness using the Plan-Do-Study-Act cycle for quality improvement processes (Langley et al., 2009).

Data Analysis

Analysis of wipe samples was performed by Bureau Veritas Laboratories. The limit of detection (LOD) varies with the antineoplastic agent, and all are reported in Table 2. Any result over the LOD was considered contaminated (Turci et al., 2003).

Descriptive analysis of data for all variables included calculation of means and standard deviations. Pre- and post-test measurements for PPE use and the predictor variables were compared using paired t tests to measure the effects of the intervention. The regression model for multivariable estimation was based on the use of directed acyclic graphs (Greenland, Pearl, & Robins, 1999) to ensure the regression models addressed the study's aims by understanding the causal assumptions and avoiding confounded models. This facilitated the selection of potential confounders. For example, when estimating the relationship between workplace safety climate and PPE use, gender, age, unit worked, perceived barriers, and interpersonal influenced were controlled.

TABLE 3. Characteristics of Survey Respondents

Characteristic	Pretest (N = 100) n	Post-Test (N = 71) n	Pretest Only (N = 33) n
Unit			
Pharmacy	11	8	2
Outpatient CT	17	14	5
Inpatient BMT	45	32	16
Inpatient oncology	27	17	10
Gender			
Male	12	10	5
Female	84	60	24
Missing data	4	1	4
Age (years)			
Younger than 25	8	1	4
25–35	43	23	13
36–45	14	20	4
Older than 45	28	21	7
Missing data	7	6	5
Race			
American Indian or Alaskan Native	3	–	1
African American	3	2	1
Asian	3	2	2
Hispanic or Latino	–	1	–
Caucasian	85	64	24
Two or more	2	1	1
Other	1	–	–
Missing data	3	1	5
Highest level of nursing education			
Diploma	1	1	–
Associate degree	11	7	4
Bachelor's degree	74	56	20
Master's degree	8	7	5
Missing data	6	–	4
Oncology Nursing Society member			
Yes	40	27	11
No	57	43	18
Missing data	3	1	4
Certified in nursing			
Not certified	58	41	14
OCN®	33	25	15
AOCNS®	2	1	–
Missing data	7	4	4
CT-handling experience (years)			
0–2	21	13	5
3–5	11	4	5
6–10	30	21	7
Greater than 10	33	28	12
Missing data	5	5	4

BMT—bone marrow transplantation; CT—chemotherapy
Note. On the short survey (N = 10), five nurses worked in inpatient BMT, and five worked in inpatient oncology; one was male, and nine were female; eight were Caucasian, and two identified as two or more races; eight were Oncology Nursing Society members, and two were not.
Note. Pretest-only participants were offered a shortened version of the pretest and were not offered the post-test.

Surveys were administered online, and data were stored securely using the Research Electronic Data Capture (REDCap) data system (Harris, Thielke, Payne, Gonzalez, & Conde, 2009), which is hosted locally by the University of Minnesota.

To address potential selection bias, a shortened survey was sent to individuals who had not completed the comprehensive survey by the deadline. The shorter survey did not address predictor variables but collected data about unit, gender, age, years of experience, and PPE use during drug-handling activities. The data analysis was performed using SAS software, version 9.3.

Results

Environmental Assessment

Overall, there were 5 surface wipe samples from a total of 62 (8%) that tested above the LOD on the pretest and 3 of 62 (5%) on the post-test. Fifty percent of the intervention samples tested positive (6 of 12). The outpatient chemotherapy infusion center was the unit with the highest number of positive surface wipe samples on the pretest (three sites) and post-test (two sites). The inpatient bone marrow transplantation and inpatient oncology units each had one contaminated area on the pretest, two during the intervention sampling, and none and one, respectively, during the post-test. One positive sample was identified at one of the two pharmacies tested—a countertop shared between pharmacy and the outpatient chemotherapy infusion center. During the post-test, that counter was negative for contamination, but the floor underneath the preparation area in the pharmacy was positive.

Survey

Overall, the survey response rate was 62% (n = 101 of 163) employees on the pretest and 71 of 100 employees on the post-test. The number of respondents declined from pre- to post-test because of attrition. Demographic results are presented in Table 3. The respondents to the full survey were similar to those who answered the short survey with respect to average age (38 years versus 36 years), years of experience (10.5 years versus 12.5 years), and reported PPE use (combined measure score of 40 versus 40.3). Reported PPE use is shown. Overall, reported glove use was high (73%–100%, depending on activity); use of gowns and double gloving were lower (25%–100% and 13%–85%, respectively and depending on activity), and use of eye protection and respirator were very low (15%–28% and 7%–17%, respectively and depending on activity). Use of double gloves and not reusing disposable gowns increased (i.e., staff became safer) from pre- to post-test. Use of gloves and gowns increased slightly for most activities.

The findings reveal that the unit in which staff worked was significantly associated with use of PPE on the pretest, adjusting for all confounders. One of the three units, the inpatient oncology unit, remained significantly lower on PPE use on the post-test compared to the reference group (inpatient bone marrow transplantation unit). Self-efficacy was significantly associated with PPE use after controlling for appropriate confounders on the pretest, but this was not the case on the post-test. Two models of workplace safety climate were estimated, which varied only by the inclusion or exclusion of the unit variable. The findings revealed the more parsimonious model, without unit, was statistically significant on the pretest, and inclusion of unit in the pretest model decreased the regression estimate from 0.5 to 0.23 and widened the confidence interval, leading to nonsignificant findings. Results of regression models are shown in Table 4. In contrast to pretest findings, the post-test results for safety climate were nonsignificant regardless of model specification.

TABLE 4. Results of Multivariate Regression

	Pretest		Post-Test	
Dependent Variable	PE	95% CI	PE	95% CI
Unit[a]				
Pharmacy	17	[3.7, 30.3]*	−10.9	[−22.9, 1.02]
Oncology	−8.9	[−17.2, −0.6]*	−11.95	[−20.9, −3]*
Masonic outpatient	−10.6	[−20.3, −0.9]*	−6	[−15.8, 3.8]
Self-efficacy[b]	1.4	[0.36, 2.45]*	0.53	[−0.34, 1.41]
Workplace safety climate[c]	0.23	[−0.1, 0.55]	0.19	[−0.19, 0.57]
Workplace safety climate[d]	0.5	[0.19, 0.81]*	0.18	[−0.21, 0.58]
Perceived barriers[e]	−0.47	[−1.1, 0.18]	−0.54	[−1.32, 0.23]

* $p < 0.05$
[a] Controlling for perceived barriers, safety climate, interpersonal influence, age, and gender
[b] Controlling for perceived barriers, age, and gender
[c] Controlling for unit, perceived barriers, interpersonal influence, age, and gender
[d] Controlling for perceived barriers, interpersonal influence, age, and gender
[e] Controlling for unit, safety climate, interpersonal influence, age, and gender
CI—confidence interval; PE—parameter estimate
Note. Data from the bone marrow transplantation unit were used as reference.

Paired t-test results are displayed in Table 5. The biggest change in the predictor variables was an increase in perceived risk after the intervention. Self-efficacy showed a significant increase following the intervention. PPE use increased for all but one unit, but the increase was significant for only one (the outpatient infusion center).

Pregnancy and Alternative Duty

Twenty-seven respondents reported being pregnant while working in their current position on the pretest and 21 on the post-test. Of those who became pregnant, four respondents on the pretest and six on the post-test reported having sought alternative duty, meaning they were not assigned patients who needed chemotherapy during the shift. Among study participants who had not been pregnant while employed at their current job (70 on the pretest and 49 on the post-test), the intent to seek alternative duty if they became pregnant varied (22 on the pretest and 10 on the post-test), and those unsure about seeking alternative work duty was similarly varied (17 on the pretest and 12 on the post-test). Comments made by male staff included, "This issue doesn't affect me since I'm male," and, "I'm a man, so I touch the chemotherapy bags barehanded."

Intervention

The intervention phase of the study involved different changes that were made on each unit based on staff feedback. Staff and management were first presented with the results and then asked to identify concerns they had for their units. The process of involving staff affected by the changes is consistent with the quality improvement literature. When a change was made, it was followed by qualitative interviewing of staff to ensure that it was feasible and improved safety. It is important to consider that the concrete changes in practice were instrumental in improving safety, in addition to the process of change, collaborative learning, and focused thinking about ways in which the units could improve work practices. Although the units had policy related to chemotherapy safe handling, the intervention involved policy and procedural updates to facilitate safety, and the evidence of contamination and focused quality improvement processes reminded staff of the reasons for it.

The bone marrow transplantation unit decided to have their nursing practice council suggest changes. This group summarized desired changes in writing after the first meeting using the framework of Plan-Do-Study-Act. The changes included (a) moving chemotherapy gowns to hallway closets rather than one location in locked room, (b) adding yellow chemotherapy disposable bags to the nurse's cart in the room, and (c) placing reminder signs about not reusing disposable gowns near the chemotherapy gowns. After three weeks of implementation, staff were surveyed online about their awareness of and thoughts about the effectiveness of the changes. The majority (n = 35) of staff surveyed were aware of the gown location change, and 37 of those surveyed reported the change had or was likely to increase their gown usage. A few respondents said it was not likely to increase their usage because they already used gowns as recommended. Moving the yellow chemotherapy disposal bags to a more accessible location also resulted in a majority of respondents (n = 37) reporting that it would increase their use. However, it was identified that replacing bags was not sustainable because of staffing. Staff satisfaction on the reminder signs was mixed. Thirty-seven people responded to the survey, and, of those, 22 approved of the change and 15 felt it was unnecessary.

Staff on this unit also recognized that nursing station technicians, who often help patients to the bathroom, lacked formal training on chemotherapy precautions. Because chemotherapy stays in the body for about 48 hours (NIOSH, 2004), it is recommended that workers use PPE when coming into contact with body fluids of patients during that time. To address this and other issues of safe handling, a training session was developed and provided to the nursing station technicians, with a pre- and post-test survey, showing that the training was effective in improving their knowledge and reported use of PPE during at-risk activities. Knowledge scores increased for all of the respondents to the survey. All respondents reported feeling better prepared to protect themselves from chemotherapy exposure on the post-test after their training.

TABLE 5. Paired T-Test Results

Variable	T Test	95% CI
PPE use by unit		
Outpatient infusion*	2.43	[0.81, 18.3]
BMT	1.79	[–0.5, 7.66]
Oncology	–0.03	[–4.49, 4.37]
Pharmacy	0.72	[–5.2, 9.5]
PPE score (all units combined)	0.48	[–4.67, 2.87]
Knowledge score	1.06	[–0.58, 0.18]
Self-efficacy*	2.33	[–1.58, –0.12]
Perceived barriers	1.24	[–2.08, 0.48]
Perceived risk*	13.58	[1.19, 1.6]
Conflict of interest	0.61	[–0.59, 1.11]
Interpersonal influence	–0.64	[–0.89, 0.46]
Safety climate	0.56	[–1.51, 2.69]

* $p < 0.05$

BMT—bone marrow transplantation; CI—confidence interval; PPE—personal protective equipment

The inpatient oncology unit also had their results shared with management and a nursing practice council. Their biggest concern was the high level of surface contamination on the nursing desk. This nursing desk was being used by healthcare staff for double-checking chemotherapy and for duties that do not involve chemotherapy handling. Because this area was contaminated, it is not safe for both types of activities. Staff were unclear as to why the desk had a high level of contamination, and, therefore, additional surfaces were tested to identify the source of this contamination. High contamination levels on the outside of IV chemotherapy bags, and observation of workflow showed that nurses were using this desk to double-check bags while going from the pharmacy to patient rooms. Most nurses did not wear double gloves when touching bags despite Oncology Nursing Society recommendations (Fonteyn, 2006). As part of the intervention, nurses were advised to consider the outside of bags as contaminated. The task of double-checking chemotherapy bags was assigned to a dedicated location in the locked medication room. The main nursing desk was cleaned on a continual basis and, upon retesting following the change, had chemotherapy levels below the limit of detection.

The outpatient infusion unit also made many changes. During quality improvement discussions, the staff discovered that reuse of disposable gowns was common practice. In the past, there had been hooks placed on walls in patient care areas to encourage reuse to save money. Following the quality improvement discussions, a policy change was implemented to discourage gown reuse. Policy also changed to include treating each outpatient bay area as a separate room, meaning that PPE had to be removed before leaving the bay area and not worn in the hallway. This was important to prevent potentially contaminated PPE being worn throughout the unit. In addition, this unit switched to an improved closed-system drug transfer device. Staff meetings were held, and the staff was encouraged to support accountability for safety behavior. Staff was also encouraged to keep dedicated shoes at work because the floors were contaminated during the pre- and post-test.

Two outpatient pharmacy areas were involved in this research. One area had no positive pretest surface contamination results and high reported PPE use. Therefore, this area was excluded from the intervention. The other pharmacy area had one area of high contamination that it shared with the nursing unit. Pharmacy staff felt this was possibly because of nursing staff wearing contaminated gowns in the hallway and leaning on the counter to return the plastic bins that held chemotherapy. In addition to the nurses' change in not wearing these gowns to that counter, the pharmacy reviewed and updated its cleaning procedure. The counter area was retested during the post-test and was not contaminated.

Discussion

Healthcare organizations teach their employees to put patient needs first. Although this is very important for patient health and safety, it is likely that patients with cancer would not want others to develop illness because of their care. Healthcare workers continue to be exposed to antineoplastic drugs, so a thorough worksite analysis must be conducted to identify potential areas of exposure. In this study, the authors found surface contamination in places where PPE use is not typical, such as commonly used counters. Identifying these areas led to changes in work processes to eliminate the exposure. For example, in the outpatient area, work practices were modified, requiring nurses to take off all potentially contaminated PPE prior to leaning on the counter. In the inpatient area, the location for double-checking chemotherapy was moved from the main nursing desk to the locked medication room. Locations with chemotherapy residue were cleaned and remained uncontaminated one month after implementation of the changes. If not for surface sampling, these units would never have known which areas were contaminated and required cleaning and critical review of associated work processes, highlighting the importance of an objective monitoring and feedback system. Tailored interventions can decrease surface contamination of a unit, but it must be preceded by a worksite analysis to see the workflow and where there are gaps in safety. The changes made as a result of these interventions are currently being sustained on the units (about six months postintervention), but it will be important to have routine annual worksite analysis and ongoing consideration of best practices for individual locations to maintain safety.

NIOSH identified a hierarchy of controls to ensure occupational safety and adequate management of exposure and human health risk. It outlines the following activities from most to least effective: elimination, substitution, engineering, administrative, and PPE (NIOSH, 2015). This and other studies have found that workers' reported use of PPE has been variable, and compliance is not as high as recommended (Lawson et al., 2012; Polovich & Martin, 2011). Because elimination and substitution of chemotherapy agents are not options because patients need chemotherapy, the authors focused interventions on the next most effective control strategies—engineering and administrative processes to improve worker protection from exposure. Engineering controls are designed to remove the hazard before it comes in contact with the worker. Moving the location of PPE to facilitate appropriate use and re-engineering work processes to remove areas where workers might be exposed was effective in changing the environment to improve worker safety rather than only relying on education.

Knowledge Translation

- Periodic surface monitoring should be performed in units where chemotherapy is used.
- Chemotherapy safety training should include all healthcare workers and support staff.
- A thorough worksite analysis and observation of work practices is necessary to understand best ways to improve chemotherapy safe handling on any given unit.

Consideration of the adoption of statewide policy regarding chemotherapy safe handling is also important. Following this study, pursuing implementation of state policy to follow the guidelines published by NIOSH in 2004 were considered. It was determined, however, that creation of a workgroup with leaders in nursing, pharmacy, medicine, cleaning, hospital planning, labor, and industry might be the best solution for the state (Minnesota). A bill to create such a workgroup was introduced in the state's house and senate.

Perceived risk increased significantly following the intervention. This is consistent with the research model that suggests increased information and discussion of potential risk will increase PPE use and improve worker safety behavior. The goal was not to scare employees; it was to remind them of their risk with objective information about their exposures.

Floors were tested in two patient care areas and the outpatient pharmacy, and all three were contaminated. One area was an inpatient bathroom floor, and another was an outpatient hallway. Staff moved their laundry bin out of the outpatient hallway and cleaned the area, but contamination persisted. It was recommended to staff that floors be considered contaminated and that they keep a dedicated pair of shoes at work to prevent bringing chemotherapy residue home. Further research could investigate cleaning products that may do a better job at erasing this persistent contamination to prevent patients and visitors from being exposed.

There were two occasions in which it was clear that support staff were not aware of their potential for exposure. One involved nurses' aides not having been trained on safety precautions, and the other was that cleaning staff were not using proper PPE when being called in to clean outpatient bathrooms. Safety training was conducted for cleaning staff by their management. This is important because it illustrates how trace chemotherapy may be inadvertently contaminating other locations.

The number of nurses who reported that they would ask for alternative duty if they became pregnant was much higher than the number who actually did ask. It is unclear if this is because priorities change once staff members become pregnant, if the survey somehow suggested that they should ask, or if staff members who work on these units enjoy their jobs and find it difficult to imagine working in another setting. In addition, 50% more nurses reported having asked for alternative duty in the post-test compared to the pretest, which may relate to the increase in perceived risk.

Limitations

Because this was a pre-/post-test study, an inherent limitation is how participants may have been influenced by the study itself. There is always the concern that it was not the intervention itself that changed things, but rather the focus on the issue (i.e., the Hawthorne effect). PPE use and the survey were collected via self-report data, which is subject to recall bias. Although observation of staff for PPE use was attempted, it was not used for validation because of concerns that it would influence the workers' use of PPE and get in the way of patient care.

Although the authors conducted environmental sampling in 39 key locations, accounting for 76 unique antineoplastic agents by location, the findings of surface contamination can vary by day, based on a variety of factors. Despite these limitations, this study is one of the first reported in the literature to test an intervention that combined a quality improvement process with data on surface contamination, PPE use, and organizational variables among inpatient and outpatient nursing and pharmacy staff. However, the survey results should be viewed somewhat cautiously because of the loss to follow-up on the post-test.

Implications for Nursing

Worksite analysis identifies specific targets for interventions to improve antineoplastic drug-handling safety. Nurses who do not typically work in oncology but may float to these areas must be made aware of hazardous drug policy. Oncology nurses should review and follow NIOSH and Oncology Nursing Society guidelines and encourage their coworkers to do the same. Oncology managers should review their workflow and policy and help create a culture of safety behavior. Administrators should fund monitoring for surface contamination of chemotherapy.

Conclusion

Healthcare workers must understand the risks associated with handling antineoplastic agents and the safe-handling precautions that reduce exposure. Units should have a safety climate that encourages chemotherapy safety. Managers must be involved in holding staff accountable for their own safety, which will improve the safety of others.

Targeted interventions decreased potential exposure. A thorough investigation involving surface monitoring and feedback from staff who worked on the units identified areas where improvement was needed. Periodic surface contamination monitoring should be mandated to identify sources of potential exposure. However, without clear policy to require such measures, it is up to healthcare professionals to monitor their oncology environments for safety and unnecessary exposures.

Although this study focused on nurses and pharmacy staff, other staff members, such as patient care assistants, cleaning staff, and delivery personnel, as well as patients' visitors, are also potentially exposed to chemotherapy. All of these populations warrant attention in future studies. All staff who work in areas where antineoplastic agents are handled must be trained to use safe-handling precautions.

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