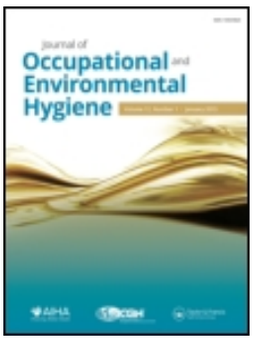

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Predictors of adherence to safe handling practices for antineoplastic drugs: A survey of hospital nurses

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ABSTRACT

Despite growing awareness of the hazards of exposure to antineoplastic drugs (ADs), surveys continue to find incomplete adherence to recommended safe handling guidelines. A 2011 survey of healthcare workers presents an opportunity to examine factors associated with adherence among 1094 hospital nurses who administered ADs.

Data for these hypothesis-generating analyses were taken from an anonymous, web-based survey of healthcare workers. Regression modeling was used to examine associations between a number of predictors (engineering controls, work practices, nurse perceptions, and nurse and hospital characteristics) and three outcomes reported by nurses: use of personal protective equipment (PPE); activities performed with gloves previously worn to administer ADs; and spills of ADs.

Adherence to safe handling guidelines was not universal, and AD spills were reported by 9.5% of nurses during the week prior to the survey. Familiarity with safe handling guidelines and training in safe handling were associated with more reported PPE use. Nurse-perceived availability of PPE was associated with more reported PPE use and lower odds of reported spills. Use of closed system drug-transfer devices and luer-lock fittings also decreased the odds of self-reported AD spills, while more frequent AD administration increased the risk. AD administration frequency was also associated with performing more activities with gloves previously worn to administer ADs, and nurse perception of having adequate time for taking safety precautions with fewer such activities.

The results suggest that training and familiarity with guidelines for safe handling of ADs, adequate time to adhere to guidelines, and availability of PPE and certain engineering controls are key to ensuring adherence to safe handling practices. Further assessment of training components and engineering controls would be useful for tailoring interventions targeting these areas.

KEYWORDS
Antineoplastic drugs; exposure controls; healthcare; hospital; nurses; oncology

Introduction

Despite growing awareness of the hazards of exposure to antineoplastic drugs (ADs), surveys of nurses and other healthcare workers who administer these drugs continue to report gaps in adherence to recommended safe handling guidelines aimed at reducing exposures to ADs.[1–4] Studies have found inconsistent use of engineering controls, personal protective equipment (PPE), and precautionary work practices.[5–9] In addition, study participants have reported adverse outcomes such as spills of ADs and skin contact with these drugs[5,9] and AD contamination has been found on hospital surfaces or in the urine of healthcare workers in a number of studies.[10–15] Research suggests that these occupational exposures likely reflect, in part, lack of adherence to precautionary measures.[16]

Identification of important predictors can provide focus for efforts to increase adherence to safe handling guidelines and decrease adverse events. A number of domains have been identified as potentially relevant to adherence among nurses: worker characteristics; workplace characteristics, including organization and practices; work hours; use of exposure controls (both engineering controls and PPE); and training.[5–8,17]

Nurse characteristics such as education level, age, years of nursing experience, and years of chemotherapy expe-

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rience were not significantly related to overall AD precautions in a study of 185 nurses and nurse managers at oncology centers.[6] However, in an earlier study of outpatient and office-based nurses, lower nursing certification level and working in the southwestern and western United States showed positive associations with gown use.[7]

Work organization and practices were associated with nurses' adherence to safe-handling precautions for ADs in the oncology center study.[6] Workplace safety climate, fewer barriers to PPE use, and lower patient load per nurse were associated with greater adherence. Studies have also examined relations between workplace characteristics and adverse endpoints, such as exposure to ADs. A survey of 1,339 oncology nurses employed in hospital outpatient and non-hospital settings found that adequate staffing and resources were protective against AD exposure, as was dose verification by two nurses.[17] Use of engineering controls such as closed-system drug transfer devices (CSTDs) and work practices such as priming IV tubing in the pharmacy have been shown to reduce floor contamination in patient care areas.[14] In addition, some studies of hospitals have found associations between accidents and working hours (shift length, total hours worked per week, and, in some cases, shift work).[18,19]

The National Institute for Occupational Safety and Health's 2011 Health and Safety Practices Survey of Healthcare Workers[20] presents an opportunity to explore whether a broad range of nurse and hospital workplace characteristics and practices are associated with adherence to safe handling guidelines or with adverse outcomes such as spills of ADs. This multimodule web-based survey was anonymous and respondents were not incentivized for their participation. Most of the 12,028 survey respondents were members of professional practice organizations. Examination of the 2,069 study participants who administered antineoplastic drugs found incomplete adherence to safe handling guidelines with, for example, 85% of respondents always wearing at least a single pair of chemotherapy gloves but only 20% always wearing the recommended two pairs of chemotherapy gloves.[5] In this larger group, comprising a variety of healthcare workers, primary reasons for not always wearing PPE were a perception that exposure was minimal and that these practices were not part of the workplace protocol and, in the case of chemotherapy gloves, not provided by the employer.[5]

The current project examines associations between a number of worker and workplace characteristics and three endpoints: PPE use; activities performed with gloves previously worn to administer ADs (hereafter referred to as "activities with potential for environmental contamination"); and spills of liquid ADs. Analyses focused on nurses who reported administering ADs in the preceding week. Nurses working for hospitals were of particular interest because they are more likely to have alternate work schedules. The intent of these hypothesis-generating analyses was to identify practices warranting further examination in the context of systematic surveys and other types of research.

Methods

The survey methodology has been described in detail elsewhere.[20] A core module included demographic and employer information, information about work organization and hours, and perception questions. The survey also included seven hazard modules. The 1,094 nurses who reported being employed by hospitals and completed the hazard module addressing AD administration were included in the current analysis.

The AD administration hazard module had 49 questions covering training, awareness of employer safe handling procedures and national safe handling guidelines, specific drugs administered, administration practices, physical form of chemotherapy, intravenous (IV) tubing priming practices, spills, skin contact/puncture, PPE use, barriers to PPE use, activities with potential for environmental contamination, and workplace medical and exposure monitoring practices. Most questions asked about practices in the seven calendar days prior to survey completion (hereafter referred to as the past week). Subsets of questions from each area were identified as predictors (Figure 1) to be considered in models for each of three outcomes (Figure 2): number of PPE items used; number of activities with potential for environmental contamination reported; and spills of liquid ADs.

Three perception questions relevant to this effort were also considered in primary analyses: whether adequate PPE was available; whether the respondent had enough time to use safety precautions while completing duties; and whether staffing was adequate to perform job duties. Alternate analyses were conducted without perception questions.

In addition, for the spill outcome, several engineering controls and practices were considered. A number of potential predictors considered for each outcome were fairly highly correlated, so tests for multicollinearity were performed before finalization of the list of predictors.

Two PPE outcome metrics were used, one for all nurses who had administered any ADs (liquid or solid) in the past week and one restricted to nurses who administered liquid ADs. Three basic recommended practices

Potential Predictors for All Outcomes

Nurse characteristics:

- Sex
- Age*
- Education (Less than bachelor's degree; bachelor's degree; master's degree or higher)
- Nursing level (staff nurse; advanced practice nurse)
- Nursing specialty (hematology/oncology nurse; other)
- Pay type (salaried; hourly/other)
- Years with current employer**
- Years in current occupation**
- Years administering ADs**

Workplace characteristics:

- Number of employees at hospital**
- Population density of hospital's location (large city; small city; suburban; rural)
- Hospital type (for profit; non-profit; public sector)
- Hospital has procedures for administration of ADs

Work organization:

- Number of healthcare employers**
- Shift length past week**
- Shift worked past week (regular day/evening; regular nights; regular shift including on-call; rotating shift; split/irregular/other)
- Number of days worked past week
- Number of days administered ADs**
- Number of AD treatments administered**
- Administered liquid ADs
- Percent of time spent in direct patient care**

Training:

- Familiar with any of four common safe-handing guidelines (American Society of Health-System Pharmacists, the National Institute for Occupational Safety and Health, the Oncology Nursing Society, and/or the Occupational Safety and Health Administration)
- Trained in safe handling of ADs past 12 months
- Ever trained in safe handling of ADs

Perception:

- I usually have enough time to take safety precautions while completing my duties
- Proper PPE is available to me
- I feel that there is adequate staffing to perform my job duties

Additional Predictors for AD Spill Outcome Only

Engineering controls:

- Use of a closed-system drug transfer device
- Use of needleless systems
- Use of luer-lock fittings (used to prevent skin punctures/cuts and possible dermal exposure to ADs) for all needleless systems, syringes, needles, infusion tubing, and pumps

Priming Practices:

- IV tubing received already primed with ADs
- IV tubing received primed with non-drug-containing fluids
- IV tubing received not primed
- Nurse primed IV tubing with ADs
- Nurse primed IV tubing with non-drug-containing fluids.

*Age was estimated by subtracting respondent's year of birth from the year the survey took place, 2011. Neither exact birthdate nor age was asked.
**Categorical response options

Figure 1. Predictors for adherence to safe handling guidelines.

Personal Protective Equipment (always versus sometimes/never/missing)

- Wore chemotherapy gloves
- Wore two pairs of chemotherapy gloves (double-gloved)
- Wore a nonabsorbent gown with closed front and tight cuffs
- Wore face/eye protection (used in analyses restricted to nurses reporting administration of liquid ADs)

Activities performed with gloves previously worn to administer antineoplastic drugs (yes/no)

- Touched IV pump or bed controls
- Touched waste basket/garbage bags
- Used pens/pencils
- Touched door knobs, cabinets, or drawers
- Used computer/calculator
- Handled files or charts
- Used a non-disposable stethoscope
- Used a phone/cellphone or pager
- Ate, drank, chewed gum, or smoked
- Used the restroom
- Applied cosmetics

Spills (question asked included number of times and amount, recoded to yes/no)

- Spill in the past week

Figure 2. Components of outcome metrics.

were components of both metrics: wearing chemotherapy gloves; two pairs of chemotherapy gloves; and a nonabsorbent gown with closed front and tight cuffs (hereafter referred to as a nonabsorbent gown). For nurses who administered liquid ADs, the second set of analyses also accounted for whether face or eye protection (guidelines recommend use when splashes are likely) was worn. The survey asked whether respondents always, never, or sometimes adhered to each practice. As the goal is consistent PPE use, for each item 1 point was assigned to respondents reporting always employing the PPE measure and 0 points to participants who reported never or sometimes using that PPE or did not answer the question. Points were totaled across items to create summary PPE adherence metric (3 points for all nurses; 4 points, including face/eye protection, for nurses administering liquid ADs).

Eleven activities with potential for environmental contamination were considered. For each item, the response choices were yes and no for whether the activity was performed with gloves previously worn to administer ADs: the summary environmental contamination score was the number of "yes" responses the subject gave.

The final outcome of interest was whether the respondent reported having a spill or leak of any amount while administering liquid ADs in the past week. Although categorical numbers and size of spills were reported by respondents, for this analysis, the outcome was treated as binary (any spill vs. no spills). Analyses of spills were limited to workers reporting administering liquid ADs during the past week.

All analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC). As the PPE and environmental contamination activity outcomes metrics have count outcomes, Poisson regression was used to identify predictors most closely associated with these outcomes, with the dscale option used to address over- and under-dispersion in the outcome distributions. For the spill/leak outcome metric, which was dichotomous (no spill vs. at least one spill of any size during the past week), logistic regression analysis was used. A backward stepwise approach was used for all analyses, with final models restricted to predictors significant at $p<0.05$. All analyses involved consideration of a large number of potential predictors. Bonferroni corrections are often used to adjust for multiple comparisons.[21] Because the current work is intended to generate hypotheses for potential follow-up in systematic surveys and therefore the larger group of predictors may be of interest, results are presented including predictors that are statistically significant before the Bonferroni correction but with notation indicating which predictors would be retained in the model following such correction.[22] The NIOSH Human Subjects Review Board determined that the activities in this project were surveillance and did not meet the criteria of research according to 45 CFR 46.1101(b)(2) and CDC Guidelines for Defining Public Health Research and Public Health Non-Research.[23]

Results

In total, 1,094 hospital nurses reported administering ADs in the past week (supplement Appendix Table A). Most of these nurses were female (96.1%), 4-year degreed (76.9%), staff-level nurses (87.5%), and nonsalaried (69.5%). Many nurses were at least mid-career, with roughly half in their current occupation (54.1%) and working for their current employer (49.8%) more than 10 years. Almost two-thirds (66.1%) were hematology-oncology nurses. The respondents worked primarily in cities of at least 50,000 people (68.2%). More than half (54.9%) were in workplaces with over 1,000 employees.

Working for a single healthcare employer was the norm for respondents (81.1%), although more than 10% reported working for more than three healthcare employers (supplement Appendix Table B). Two-thirds spent more than 75% of their work time performing direct patient care. Five-day workweeks were most common (41.6%), followed by 4-day (27.4%). Regular daytime and evening shifts were common (78.0%), but 10% of respondents worked night shift and slightly more worked other schedules such as regular shift with call and rotating shifts. Half of the group worked 9–12 hr shifts, with most others working 8-hr shifts.

Almost all respondents (supplement Appendix Table C) reported that their employer had procedures addressing safe administration of antineoplastic drugs (95.2%) and that they had been trained on safe handling at some point (95.4%). However, 22% of respondents did not report familiarity with any of the four guidance documents on safe handling, and 34% had not been trained in the last year. While approximately 92% of respondents agreed or strongly agreed that proper PPE was available to them, fewer (85.8%) agreed/strongly agreed that they had enough time to take safety precautions. Only 63% agreed or strongly agreed that staffing was adequate for them to perform their job duties; 36.9% disagreed/strongly disagreed with this statement.

Almost two-thirds of respondents (63.3%) administered four or fewer AD treatments during the past week (supplement Appendix Table D). Half (50.7%) reported administering these drugs three or more days of that week. The 3.8% of respondents who did not administer ADs in liquid form were excluded from spills analyses but retained in other analyses.

The mean number of PPE practices the nurses reported adhering to (Table 1) was less than two (of three total, or

Table 1. Responses for components of outcome metrics.

Outcome	Characteristic	Number (%) or mean (SD)
Antineoplastic drug (AD) administration past week	Administered liquid or solid Ads	1094 (100.0)
	Administered liquid Ads	1045 (95.5)
Use of Personal Protective Equipment (PPE) Practices (respondents = 1094, 1045 administering liquid ADs)	Mean # PPE practices adhered to (out of 3)	1.76 (0.86)
	Always wore at least one pair of chemotherapy gloves	953 (87.1)
	Always wore two pairs of chemotherapy gloves	252 (23.0)
	Always wore a nonabsorbent gown with closed front and tight cuffs	715 (65.1)
	Mean # PPE practices adhered to (out of 4) for nurses administering liquid ADs (including face/eye protection)	1.94 (0.95)
	Always used face/eye protection (of respondents who administered liquid ADs)	146 (14.0)
Activities performed with gloves that had been used to administer AD (respondents = 1089)	Mean # (SD) activities reported out of 11 total	1.72 (1.74)
	Touched IV pump or bed controls	716 (65.5)
	Touched waste basket/garbage bags	297 (27.2)
	Used pen or pencil	249 (22.8)
	Touched door knobs, cabinets, or drawers	218 (20.0)
	Touched a computer keyboard, mouse, monitor, or calculator	138 (12.6)
	Handled files or charts	115 (10.5)
	Used a non-disposable stethoscope	73 (6.69)
	Used phone/cell phone/pager	40 (3.67)
	Ate, drank, chewed gum, or smoked	22 (2.02)
	Used restroom	3 (0.27)
	Applied cosmetics	2 (0.18)
Spills/leaks of ADs (respondents = 1044)	Spill past week (of those administering liquid antineoplastic drugs)	
	Yes	99 (9.48)
	No	945 (90.5)

SD = standard deviation

four total when administering liquid ADs). While most nurses reported always using chemotherapy gloves, and more than half always used a nonabsorbent gown, only one in four always double-gloved. Of those who administered liquid ADs, only one in seven always used face and/or eye protection during administration.

The mean number of activities with potential for environmental contamination was also less than two (of 11 possible). Touching the IV pump or bed controls while wearing gloves that had been used to administer ADs was by far the most common, and was reported by more than half of respondents. Very few respondents reported using the restroom or applying cosmetics while wearing these gloves.

Having at least one spill during the past week was reported by approximately one of ten nurses.

Modeling results

Table 2 shows statistically significant predictors of consistent PPE use. Variates with positive parameter estimates are associated with greater reported PPE use. Training-related items, PPE availability, and familiarity with safe handling guidelines had the strongest positive associations with PPE use.

In the three-item PPE model, familiarity with guidance documents and training (whether within the past year or earlier) were associated with more PPE use. The perception that adequate PPE was available was also associated with increased PPE use, as was the hospital having procedures for safe administration of ADs. In contrast, male nurses appear to use less PPE. When perception questions were excluded from the models, the finding for male nurses was no longer statistically significant, but all other predictors were retained in the model (data not shown for models excluding perception questions).

When respondents were restricted to nurses administering liquid ADs and the use of face and/or eye protection was added to the PPE metric (four-item model), familiarity with guidelines and training within the last year were again significantly associated with more PPE use, but other components of the final models differed. The number of times the nurse administered ADs during the week had a statistically significant, negative association with PPE use, and nurses who had administered ADs for more years used fewer PPE items. Omitting perception questions resulted in the addition of two items to this model: sex (with male nurses reporting using fewer PPE items) and training prior to the previous year

Table 2. Predictors of reported use of personal protective equipment (PPE) while administering antineoplastic drugs (ADs) in past week: final models.

Outcome metric	Predictor	Rate Ratio (95% confidence interval)
3 PPE items (wearing chemotherapy gloves, wearing two pairs of chemotherapy gloves, wearing nonabsorbent gown) All hospital nurses	Nurse reports "proper PPE is available to me"[a]	1.09 (1.04–1.14)
	Employer has procedures for administration of ADs	1.21(1.00–1.46)
	Familiar with safe handling (SH) guidance documents*	1.21 (1.10–1.32)
	Trained in SH in last year*	1.80 (1.44–2.25)
	Trained in SH > 12 months ago*	1.67 (1.33–2.10)
	Sex (male)	0.85 (0.73–1.00)
4 PPE items (3 items above + wearing eye or face protection) Restricted to hospital nurses who administered liquid antineoplastic drugs	Nurse reports "proper PPE is available to me"*	1.11 (1.05–1.17)
	Employer has procedures for administration of ADs	1.32 (1.08–1.61)
	Familiar with SH guidance documents*	1.20 (1.10–1.32)
	Trained in SH in last year	1.09 (1.01–1.17)
	Duration (years) administering ADs	0.97 (0.94–0.99)
	Total AD treatments administered during week	0.96 (0.93–0.98)
	Sex (male)	0.82 (0.70–0.96)

[a] Retained after Bonferroni correction.

(associated with more PPE use). Multicollinearity testing did not lead to the removal of any candidate independent variates from this or the other outcomes.

Several predictors were associated with nurses reporting more activities with potential for environmental contamination (indicated by positive parameter estimates in Table 3). These included working more years as a nurse; administering ADs more days of the past week; higher education level; and working for a hospital in a rural area. In contrast, reporting having enough time to take safety precautions was associated with fewer activities with potential for environmental contamination, as was increased age. Omitting perception questions produced no changes in other predictors included in the final models.

Specific engineering controls, and perception of PPE availability appear to be protective against reported spills (Table 4). The use of two types of devices designed to prevent exposure, CTSDs and luer-lock fittings, were associated with statistically significant reductions in spills, though use of a needleless system itself was not associated with lower likelihood of spills. The perception of PPE

Table 3. Predictors of activities with potential for environmental contamination[a]: final model.

Predictor	Rate Ratio (95% confidence interval)
Nurse reports "I usually have enough time to take safety precautions while completing my duties"[b]	0.78 (0.72–08.6)
Age[b, c]	0.98 (0.98–0.99)
Number of days nurse administered ADs in past week[b]	1.10 (1.05–1.15)
Education level[b]	1.26 (1.15–1.38)
Years in current occupation	1.08 (1.02–1.15)
Hospital in rural area	1.39 (1.08–1.79)

[a] The score comprises one point for each activity the respondent acknowledged performing during the past week with gloves previously worn while administering ADs: touching IV pump or bed controls; touching waste basket/garbage bags; using pens/pencils; touching door knobs, cabinets, or drawers; using computer/calculator; handling files or charts; using a nondisposable stethoscope; using a phone/cellphone or pager; eating, drinking, chewing gum, or smoking; using the restroom; or applying cosmetics.
[b] Retained after Bonferroni correction.
[c] Age was estimated by subtracting respondent's year of birth from the year the survey took place, 2011. Neither exact date of birth nor age was asked.

Table 4. Predictors of reported spills[a] of liquid antineoplastic drugs (AD) in past week: final model.

Predictor	Odds ratio (95% confidence interval)
Nurse reports "proper PPE equipment is available to me"[b]	0.53 (0.39–0.72)
Always used a closed-system drug transfer device (CSTD, e.g., PhaSeal)	0.54 (0.34–0.87)
Always used luer-lock fittings for all needleless systems, syringes, needles, infusion tubing, and pumps	0.35 (0.17–0.72)
Nurse primed IV tubing with ADs	2.52 (1.22–5.24)
Number of days nurse administered ADs (in past week)[b]	1.34 (1.06–1.69)
Number of times nurse administered ADs (in past week)	1.28 (1.01–1.61)

[a] At least one spill of any size
[b] Retained after Bonferroni correction.

availability was also associated with a decreased spill risk. Nurses who themselves primed IV tubing with ADs were more likely to report spills. However, nurses who received tubing already primed with ADs (as opposed to recommended non-drug containing fluids) did not have a statistically significant increase in reported spills. Frequency of administration was also associated with greater likelihood of a spill. Perception of PPE availability (protective) and the number of days the nurse administered ADs (increased spill risk) were retained after Bonferonni correction (data not shown).

With perception questions excluded, the employer having procedures for proper handling of ADs showed a statistically significant association with a lower spill risk, and the number of times administering ADs was no longer statistically significant (though number of days administering ADs continued to be associated with increased spill risk). A final analysis to assess predictors not contingent on the availability of engineering controls included perception items but excluded safe-handling devices. In this analysis, availability of proper PPE, whether the nurse primed tubing with ADs, number of days the nurse administered ADs, and whether the hospital had procedures for safe handling of ADs were retained, with associations in the same directions as reported for the other models (data not shown).

A number of predictors did not meet statistical significance criteria for any of the three outcomes and were not included in final models. These included pay type, duration with current employer, education level, nursing level and specialization, hospital size, mandatory overtime, shift and shift length, number of healthcare employers the nurse had, and number of days worked during the week. In addition, the respondent's perception of adequate staffing was not part of any final model.

Discussion

Reported adherence to recommended practices for safe handling of ADs was not universal in this group of hospital nurses, but analyses of predictors of adherence point to potential targets for further study and intervention. Training, availability of PPE, use of engineering controls, and provision of adequate time to adhere to safe handling practices all appear to warrant attention.

Perceived PPE availability, familiarity with safe handling guidance documents, training in safe handling of ADs, and working for an employer with procedures for safe handling were associated with more PPE use. Recent training (in the last 12 months) was of particular importance, although for some PPE use metrics, more remote training was also associated with increased use. Studies have found evidence of AD contamination on floors of patients' rooms,[12,13] so use of shoe covers, although not recommended PPE for AD administration and therefore not considered in these models, could be important for reducing healthcare worker exposure to ADs. For core PPE (nonabsorbent gown, chemotherapy gloves, and double chemotherapy gloves), institutional safe-handling procedures and employee familiarity with safe-handling procedures (including continued training) appear to be key.

Activities with potential for environmental contamination were more common with more frequent AD administration (days administered per week and/or total treatments administered per week). This relation may reflect, in part, more opportunities for environmental contamination activities and spills. In general, objects touched most frequently with gloves previously worn to administer ADs were those most closely related to patient care and those that were part of or located in proximity to AD administration (touching the IV pump or bed controls, followed by touching waste basket/garbage bags, using pens/pencils, and door knobs, cabinets, or drawers). Activities which were optional and could be conducted at a distance from the administration area (eating, applying cosmetics) were rarely conducted wearing used gloves. The perception of having enough time to take safety precautions was associated with fewer environmental contamination activities. Collectively, these results suggest that insufficient time to adhere to glove doffing and donning practices while performing core nursing functions in areas where ADs are administered may lead to greater potential for environmental contamination.

Better understanding of the components of perceived PPE availability, such as where different PPE items should optimally reside in relation to AD administration areas, would be helpful for employers who wish to encourage adherence and decrease potential for environmental contamination, as would identification of specific barriers to PPE use. The survey results on activities with potential for environmental contamination suggest that gloves are being worn during other nursing activities after they have been used to administer ADs. Interestingly, touching computer equipment while wearing potentially contaminated gloves was reported by just over 1 in 10 nurses; future research should reexamine this issue as such devices are more frequently brought into patient care areas. Collectively, the data on PPE use and environmental contamination point to the need to address not only the need for consistent use of PPE but also when, where, and how used gloves should be removed. Transitions between activities appear to be particularly important.

Both PPE availability and administration frequency were also associated with nurse-reported spills, as were several engineering controls and work practices. Other studies have found that engineering and administrative controls reduce contamination: centralizing IV tube priming in pharmacies reduced floor contamination in patient care areas;[14] use of CTSDs also reduced contamination in patient therapy rooms[24] and such practices have reduced levels of detectable ADs in urinary samples taken from hospital nurses who administered ADs.[25]

In these analyses, use of two engineering controls, CTSDs and luer-lock fittings, were associated with reporting zero spills, but use of needleless systems had no statistically significant association with spill occurrence. The survey did not address reasons for not using engineering controls, so whether the equipment was not available or whether technical or workflow issues precluded its consistent use could not be determined. In this survey, nurses' receipt of tubing pre-primed with either a non-drug containing fluid (best practice) or with ADs (a practice that increases the risk of exposure to these drugs) showed no statistically significant relation with occurrence of spills. This contrasts with previous findings.[14] However, studies reporting protective effects for tubing pre-primed with non-drug containing fluids used measured contamination or exposure, rather than self-reported spills, as the outcome. The self-reported spill metric used in the current study may be biased towards larger spills or spills of colored ADs, as smaller spills and spills of colorless liquids may not have been noticed. The finding in this study that nurses who primed tubing with ADs themselves were significantly more likely to report a spill supports the need for centralized priming of IV tubing (with a nondrug containing fluid). That spills during the past week were reported by almost 10% of the respondents highlights the importance of consistent use of preventive measures.

Despite extensive research suggesting associations between work hours and hospital safety, no metrics for work hours were included in final models for the three outcomes examined here. However, the potential impact of work hours on safe handling practices cannot be ruled out, as data on work hours in this survey had limitations. Restrictions on overall length of this multi-module survey precluded obtaining detailed information on factors such as direction of shift rotation, hours of split shifts, and recovery time between long shifts. Data on total hours worked across all jobs could not be used because some respondents apparently misinterpreted the instructions and re-entered hours worked in the primary job as hours worked in other jobs, yielding total hours worked for the week that were not realistic.

Inpatient and ambulatory care settings differ in a number of ways, including some that likely impact adherence. Although we restricted analyses to nurses reporting being employed by a hospital, we could not determine conclusively which nurses worked in ambulatory care settings and which in the inpatient environment. Indeed, with increasing trends of purchase of physicians' practices by hospitals and the administration of chemotherapy in outpatient settings located within or adjacent to hospitals, the lines between these two settings may be less clear cut.[26]

Some additional limitations apply to this survey, which was a targeted sample and may not be generalizable to the larger population of hospital nurses who administer ADs. Adherence to safe handling measures may be higher in the survey respondents than in the general population of nurses because survey respondents were members of professional practice organizations and possibly more aware of health and safety issues than their non-member counterparts;[5] moreover, well over half of the hospital nurses who administered ADs were hematology-oncology nurses.

The outcome metrics used in this study are based on nurses' self-reports and cannot be validated independently. In a study of the influence of nurses' knowledge, attitudes, and behaviors on adherence to safe handling practices, nurses' knowledge of the risks of ADs was associated with better self-reported adherence; however, observation of a small sample of the nurses found that adherence was lower than that calculated from self-reports.[16] Confirmation of the current findings in the context of a study design allowing both observation of adherence and measures of environmental contamination and nurse exposures would be helpful, although difficult to implement on a large scale.

Researchers continue to assess the effects of and update best practices and engineering controls.[27–30] Frequent updating of guidelines to cover new research-based information pertinent to safe handling guidelines is crucial. Significant practice changes, including mandatory use of CSTDs, for nurses administering ADs will be incorporated in USP Chapter 800.[31] The results of this survey suggest the need for ongoing training and assessment of work structures to ensure adherence to this and other new guidelines.

Conclusion

The current study is one of the largest to assess adherence to safe-handling guidelines for administration of ADs as reported by hospital nurses. Adherence to best practices for safe administration of antineoplastic drugs requires the efforts of employers (engineering controls, training, provision of PPE, and adequate time for adherence) and healthcare workers (seeking out training, consistently

following facility procedures, and reporting safety concerns). Positive associations between use of engineering controls, nurse-perceived availability of PPE, and nurse-perceived adequacy of time to take safety precautions and desirable outcomes—reflecting adherence to guidelines—point to the need for work structures and equipment that support adherence. While providing optimal equipment and adjusting workflows to ensure adequate time to take safety precautions may be difficult in the current health-economic climate, the results of this study suggest potential benefits in terms of both reduced exposures and reduced downstream healthcare costs for hospital personnel.

Disclaimer

The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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