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Predictor Factors Associated With Hazardous Drug Safe Handling Precautions Across a UK Oncology Nurse Sample and Implications for Novel Treatments

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A B S T R A C T

Objectives: The development and use of novel systemic anticancer therapy (SACT) treatments are advancing rapidly. While cytotoxic drugs have traditionally been the cornerstone of treatment, they are increasingly used alongside novel agents. This study aims to assess factors affecting adherence to safe-handling precautions, enhance safety protocols, and minimize potential occupational exposure to hazards in clinical environments, increasing their capacity for novel treatments.

Methods: Cross-sectional, online survey of oncology nurses across the UK who handled SACT. Participants were asked to complete the *Factors Predicting Use of Hazardous Drug Safe-Handling Precautions* Questionnaire. Descriptive analysis, Spearman rank correlation coefficients, and regression analysis were performed to determine the predictors of precautionary use when handling HDs.

Findings: Analysis of (n = 675) participants revealed high knowledge of exposure, high self-efficacy, low perceived barriers, moderate perceived risks, high interpersonal influence, low conflict of interest and moderate safety climate in the workplace. The analysis of the data also indicated weak positive correlations between age and knowledge (rs = 0.093), self-efficacy (rs = 0.103) and safe-handling scores (rs = 0.082); the age of the participants has a weak negative correlation to perceived barriers (rs = −0.141), conflict of interest (rs = −0.116), and workplace safety climate(rs = −0.116). Notably, safe handling scores showed no significant correlation with other theoretical predictors. Comparison between government and private sector nurses (n = 76) demonstrated higher patient volumes F (15.807, 74), $P < .001$ and significantly lower safe handling scores in the government settings F (4.135, 74) $P < .05$.

Conclusions: Nurse-patient ratios between government and private sector settings predict global safe-handling precautions.

Implications for practice: Novel treatments for nurse-patient ratios are essential, as new therapies and schedules further create additional workload pressures that may reduce safe handling practices.

The term Systemic Anticancer Therapy (SACT) has evolved from its earlier definition, which primarily referred to Cytotoxic Drugs (CDs), to encompass a broader range of treatments, including novel agents that are cytostatic rather than cytotoxic in nature.[1] Despite this shift, CDs remain the cornerstone of many SACT regimens. Numerous treatment schedules incorporating novel SACT agents also include traditional CDs, emphasizing their continued importance in oncology.[2] Consequently, introducing innovative therapies has not diminished the critical need to educate SACT nurses about the hazards and safe handling.[3-4] Ensuring robust knowledge of potential occupational exposure and adherence to existing safe practices remains essential with increasing novel treatments as they pose significant workload-associated safety issues for oncology nurses involved in handling, administration, and disposal of CDs regardless of the healthcare setting.[5]

Occupational exposure can occur through various routes, either oral,[6] intravenous or intrathecally, and can be absorbed through the skin, inhalation, or ingestion.[5] Direct contact with the drug or exposure to drug-contaminated surfaces, equipment, or air can result in absorption into the body. Skin contact is a standard route of exposure, particularly when near contaminated surfaces or during drug administration.[7-10]

SACTs, by nature, are designed to target and kill rapidly dividing cells, a characteristic of cancer. However, these drugs do not

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Layperson summary

What we investigated and why

It is important to understand the nurse's potential for workplace exposure to chemotherapy. We investigated the ability to predict factors associated with cancer nurses adhering to safe handling precautions when giving people living with cancer receive their chemotherapy treatment.

How we did our research

To do this research we asked cancer nurses to complete a questionnaire that measured their knowledge of the hazard, their perceived risk of the hazard and their perceived barriers to practicing safe handling precautions. We also asked them about the availability of personal protective equipment and what their co-workers practice of safe handling precautions were.

What we have found

We found that cancer nurses were knowledgeable and confident in their safe handling practices. We also found they reported less barriers to accessing personal protective equipment, allowed them to practice safe handling precautions. We also found that high patient numbers affected their ability to keep to the safe handling practices.

What it means

This means that when nurses are asked to treatment more patients with new complex novel drugs, this may make their workload higher and create an environment that might cause the nurse's practice unsafely when delivering cancer treatment and that they may be exposing themselves to an occupational risk which could affect their health.

distinguish between malignant and healthy, rapidly dividing cells, leading to a range of adverse effects and risks of exposure.[5,11] Oncology nurses, through direct handling of these cytotoxic agents, face occupational risks such as acute symptoms (e.g., skin irritation, nausea) and long-term effects (e.g., reproductive issues, increased cancer risk) if safety protocols are not rigorously followed.[12]

The significance of maintaining safety in SACT administration cannot be overstated.[13-16] The method of control includes wearing appropriate personal protective equipment (PPE), implementing engineering controls (e.g., closed systems devices), using proper techniques for drug preparation and administration, and following proper waste management procedures.[5,11,17] Regular monitoring, evaluation, and education are essential to maintaining a safe working environment for nurses handling cytotoxic drugs but are rarely adhered to.[15]

Theoretical factors predicting the use of hazardous drugs and safe-handling precautions among oncology nurses can draw from behavioral and organizational frameworks. These theoretical frameworks emphasis the complex interplay of individual beliefs, social influences, and organizational context in predicting the use of hazardous drug safe-handling precautions.[18-20]

One theoretical framework, the *Theoretical Factors Predicting the Use of Hazardous Drug Safe-Handling Precautions* by Polovich and Clarke (2012),[20] has been used to understand factors influencing the usage of PPE among the oncology nurses involved in handling and administering hazardous drugs to patients. This theoretical framework underpins a validated survey implemented globally.[21-28] Studies have found different factors significantly associated with PPE whilst handling SACT. Organizational factors include the number of patients,[21,22,25,27,28] profit and non-profit healthcare settings,[24] and workplace safety climate,[20,22,23,28] whereas age and conflict of interest were negatively predictive.[27,28] In the UK, two studies have been conducted in a discrete population, with only descriptive analysis.[10,29]

As novel SACT therapies will change the landscape of workload allocation within SACT units in the UK requiring preparation and administration alongside existing SACT protocols.[30] There is a need for stringent safety measures to be evaluated as novel SACT treatments become more prevalent. Therefore, generating baseline insights is essential to understand and enhance staff safety, reduce occupational exposure to hazards, and ensure appropriate review and compliance with established guidelines.

Current research has not fully explored how clinical challenges such as staff-patient ratios and resource allocation affect adherence to existing safe handling precautions. Therefore, this study seeks to inform policymaking and support the safe integration of novel therapies within the current capacity of the UK healthcare systems.

The present study aimed to evaluate factors influencing adherence to safe-handling precautions in clinical settings among UK oncology nurses administering SACT by analyzing variables such as knowledge, confidence in self and others, and the organization's role in providing a safe working environment, including nurse-patient ratios, SACT experience, availability, and use of protective equipment.

Material and Methods

A cross-sectional survey study was conducted from October 2022 to July 2023 and distributed by the National UK Oncology Nursing Society. The survey, based on *theoretical factors predicting the use of safe handling precautions* for hazardous drugs,[20] was reviewed by a UK-represented stakeholder group for content consistency and applicability.

The survey included fourteen sections with questions on predictors of Use of Hazardous Drug safe handling precautions, personal knowledge of hazard, organizational influence/ workplace safety, conflict of interest, perceived risk, self-efficacy, perceived barriers, and interpersonal influence (Supplementary material one or Table 1).[20]

Hazardous Drug Handling Questionnaire: Theoretical Predictors in the Survey

The responses collected were coded, and the scores were calculated for each participant. The section-wise scores of the participants were later compared for any correlation to the theoretical predictors.

Knowledge of hazard: The 12-item Hazardous Drug Exposure Knowledge scale measures knowledge about hazardous drug exposure. Response options are true, false, and do not know. Correct responses receive a score of 1, and others receive 0. Possible scores range from 0 to 12, with higher scores indicating higher knowledge.

Seven items measured self-efficacy, with four response options ranging from strongly disagree to strongly agree. The potential range of scores is 7-28, with higher scores indicating higher self-efficacy.

The 13-item perceived barriers to using the PPE scale has four response options, from strongly disagree to agree strongly. Scores can range from 13 to 52; higher scores indicate higher perceived barriers.

Perceived risk was measured using three items with four response options, from strongly disagree to strongly agree. The potential range of scores is 1-4, with higher scores indicating a higher perceived risk of harm from HD exposure.

Interpersonal influence was measured using four items: one measuring a person's beliefs regarding how much co-workers think they should use PPE and three measuring how often other nurses use

TABLE 1
Adapted Theoretical predictors variables[20]

Predictor Variables	Description	Sample Question	Number of items	Response question
Knowledge of hazard	Knowledge about Hazardous exposure and usage of PPE	CDs can enter the body by breathing it in	12	True, False, don't know
Self-Efficacy	Confidence in using the PPE	I am confident that I can use PPE properly	7	Four-point scale from strongly agree to strongly disagree
Perceived Barriers	Address the need for and efficacy. of PPE, time for use, and other physical and emotional discomfort hindrances to wearing PPE	I don't think PPE is necessary	13	Four-point scale from strongly agree to strongly disagree
Perceived risks	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 CDs is a serious problem at work	7	Four-point scale from strongly agree to strongly disagree
Interpersonal influence	How often do coworkers use PPE and how important the respondent feels the use of PPE is for coworkers	How often do the following people wear personal protective equipment when handling CDs?	7	Four-point scale from strongly agree to strongly disagree
Perceived Conflict of Interest	How PPE use might be affected by the conflict between the need for self-protection and the need to provide patient care.	Wearing personal protective equipment makes my patients worry	6	Four-point scale from strongly agree to strongly disagree
Work safety climate	Accessibility of PPE, how safety is assessed by managers, training, the cleanliness of the workplace, coworker support, and safety policy	Gloves for CDs are readily accessible in my work area	21	Five-point scale, from strongly agree to strongly disagree (Includes neutral)

protective equipment. The potential range of scores is 0−20, with higher scores indicating a more positive view of co-workers' attitudes toward and use of PPE.

Conflict of interest was measured using six items adapted from the Healthcare Worker Questionnaire. The four response options range from strongly agree to strongly disagree for a range of 6-24, with higher scores indicating higher conflict of interest.

The workplace Safety Climate questionnaire had 21 items with five response options from strongly disagree to agree strongly. The potential range of scores is 21-105, with higher scores indicating a better safety climate.

Total HD safe-handling precautions (global precautions) are the mean score for five items each from the administration and disposal scales (use of gloves, double gloves, CD gowns, eye protection, and respirators). The maximum score of five or higher indicates greater use of safe-handling precautions. Total precautions (mean score for Administration and Disposal) range from 0 to 5, with a higher score indicating greater use of safe-handling precautions. The Total safe-handling precautions (UK precautions) is the mean score for three items from the administration and disposal (use of CD gloves, other gloves and plastic aprons). The maximum score of five or higher indicates greater use of safe-handling precautions. Total precautions (mean score for Administration and Disposal) range from 0 to 5, with a higher score indicating greater use of safe-handling precautions.

Population and Sampling

The survey was open to any oncology nurses practicing in the UK who were willing to participate and consent to the study. Nurses who had yet to gain experience handling CDs or administration to patients or nurses practicing in other countries or the EU were excluded from the study. Convenience sampling was applied with dissemination routes that allow maximum recruitment capacity. Recruitment for the survey was sought through advertisements and reminders on the social media pages of the UK Oncology Nursing Society(UKONS). The distribution created a snowball effect amongst the participants, who encouraged other cancer non-UKONS members to participate in the survey.

Data Collection

A Novi survey tool distributed a questionnaire through a link for the participants to complete anonymously (no identifiable details were obtainable). Informed consent was obtained after the participants had reviewed the privacy statement and participation information sheet. The questionnaire was received electronically and stored on a secure database at the university site. The university granted ethical approval. Edinburgh Napier University (SHSC2895752). A random sampling method was employed, which gave every individual in the population an equal chance of participating. The population was reviewed for proportional participation across the four nations of the UK, including age, oncology and SACT administration experience.

Data Analysis

Data collected was analyzed using SPSS (version 26.0). Descriptive data was calculated using the questionnaire responses' percentages, frequencies, mean, and standard deviations. The theoretical predictor scores were calculated by coding the responses and calculating the scores for knowledge of hazard, self-efficacy, perceived risks, perceived barriers, interpersonal influence, conflict of interest and organizational influence/workplace safety. Descriptive data and statistical tests, including the Kruskal Wallis H test, Spearman's correlation coefficient, and Multiple regression analysis (n>200) were conducted. The p-value ($P < .05$) was considered statistically significant. The statistical analysis of the theoretical predictor scores of the survey participants was done, and bivariate correlations between sample characteristics and safe handling were performed. Multiple regression analysis was performed with the significant predictor variables, examining for a substantial change in R2. The study aimed to investigate the relationship between Safe handling scores and the other theoretical predictors such as knowledge scores, self-efficacy scores, perceived risk scores and the number of patients treated by each Nurse in their facility.

Results

Participant Characteristics

858 nurses who handled SACT participated in the survey (Table 2). 675 nurses answered all the sections, including the demography, and the other participants (n = 183) answered the sections partially and thought only relevant to them (Table 2). Education levels were reported as participants achieving a diploma (24.2%), bachelor's degree (60.6%), and master's degree (15.1%). The mean age of the

TABLE 2
Participant Characteristics, Personal and Nurse-Patient Ratio and Administering Unit -Patient Ratio Factors

Demography	Total number of respondents	% of respondents
Survey responses	**858**	
Participants with demography info	**675**	**78.6%**
Participants who chose to remain anonymous (no demographic details)	**183**	**21.4%**
Participants with demographic information	**675**	**%**
Gender		
Female	621	92.0
Male	45	6.7
Others	1	0.1
Not disclosed	8	1.2
Education level		
Diploma	164	24.3
Bachelor's degree	409	60.6
Masters	102	15.1
Age range		
21-30	116	17.2
31-40	215	31.9
41-50	170	25.2
51-60	151	22.4
above 60 years	23	3.4
Mean age of the participants[a]	**41.3 Years**	
Nursing experience		
1 to 5 Years	113	16.6
6 to 10 Years	143	21.2
11 to 15 Years	125	18.5
16 to 20 Years	75	11.1
More than 20 Years	219	32.4
Mean Nursing experience[a]	**14.3 Years**	
Oncology nursing experience		
1 to 5 Years	220	32.6
6 to 10 Years	156	23.1
11 to 15 Years	97	14.4
16 to 20 Years	76	11.3
More than 20 Years	126	18.7
Mean Oncology Nursing experience[a]	**10.9 Years**	
Chemo handling experience		
1 to 5 Years	242	35.9
6 to 10 Years	155	23.0
11 to 15 Years	93	13.8
16 to 20 Years	73	10.8
More than 20 Years	112	16.6
Mean Chemo Handling experience[a]	**10.3 Years**	
Patients treated per nurse	8.17±10.04	
Patients in each unit	44.05± 42.133	

[a] Mean was calculated after calculating the midpoint of the age range and their experiences in nursing, oncology and chemo handling.

participants was 41.3 years; the average nursing experience was 14.3 Years; the mean oncology nursing experience was 10.9 years; the mean CD handling experience was 10.3 years. Ninety-eight per cent (n = 661) had training in oncology nursing, and 2% (n = 14) did not have a training history. Just under 76% (n = 509) were members of the UKONS. The mean number of patients handled by nurses each day was 8.17 ± 10.043, and the mean number of patients treated in the unit per day was 44.05 ± 42.133.

Theoretical Predictor Variables Among Participants

The overall descriptive statistics of the theoretical framework variables are displayed in Table 3. The knowledge of hazard scores were high among the nurses, with a mean score of 10.4 ± 1.37. The participating nurses reported high self-efficacy with a mean score of 22.3 ± 3.72. Interpersonal influence scores were high among nurses, with a mean score of 17.7 ± 3.2. Perceived risk scores were moderate, with a mean score of 2.8 ± 0.34. Work safety climate scores were moderate, with a mean score of 84.6 ± 14.3. Perceived barrier scores were low among the nurses, with a mean score of 20.3 ± 5.62. Survey results indicate low conflict of interest scores among the nurses, with a mean score of 8.96 ± 3.05.

PPE Usage During Different Procedures and the Total Safe Handling Precautions

Total safe handling precautions (mean score for Administration and Disposal) range from 0 to 5, with a higher score indicating greater use of safe-handling precautions. Response options were coded as 0 = never, 1 = 1%-25%, 2 = 26%-50%, 3 = 51%-75%, 4 =76%-99%, and 5 = always for calculating the mean score for each participant. Total HD safe-handling precautions (Global) are the mean score for five items each from the administration and disposal scales (use of CD gloves, double gloves, CD gowns, eye protection, and respirators). The maximum score is five and higher, which indicates greater use of safe-handling precautions. The mean safe handling score for administration was 1.48 and 1.44 during the disposal of CDs. Six hundred two survey participants handled administration and disposal of the CDs in their practice. Total safe-handling precautions were measured using the 10 items for administration and disposal. Total HD safe handling precaution use was 1.46 (SD = 0.94, range 0-4.5). The total safe handling precautions (UK) are the mean score for three items each from the administration and disposal scales (use of CD gloves, other gloves and plastic aprons). The mean safe handling score for administration was 3.36 and 3.35 during the disposal. The total safe handling precautions (UK) was calculated at 3.36 (SD = 0.62, Range 1.33-5.0)

The safe handling precaution scores of the participants of the survey are displayed in Table 3. The percentages of the various PPE used were calculated by adding the frequencies of always used to very rarely used categories answered by the participants. Usage of gloves labelled for use with CDs was highest in the disposal of CDs (63% n = 386), followed by administration (62% n = 412) and handling excreta (59% n = 279). Plastic aprons were used instead of CDs-designated gowns by 97% during administration, 96% during disposal, and 98% during handling excreta. Eye protections were used less during handling excreta (32% n = 147), disposal of CDs (37% n = 229), and by 42% (n = 279) during administration. Masks/respirators were used by 50% (n = 334) of participants during administration, 47% (n = 292) of participants during disposal of CDs, and 47% (n = 216) during the handling of excreta.

Relationship Between the Theoretical Variables and Demographic Characteristics

The Spearman rank correlation values (rs) when comparing the theoretical predictor scores among the age of participants, nursing experience, oncology nursing experience, CDs handling experience and number of patients treated in the unit are shown in Table 4. The age of the participants had a weak positive correlation to knowledge (rs = 0.093), self-efficacy (rs = 0.103), and safe handling precaution score (rs = 0.082). Similarly, the age of the participants had a weak negative correlation to perceived barriers (rs = −0.141), conflict of interest (rs = −0.116), and workplace safety climate (rs = −0.156).

Years of nursing experience had a weak positive correlation to self-efficacy (rs = 0.133), workplace safety (rs = 0.171), and safe handling precaution score (rs = 0.085). Years of nursing experience had a weak negative correlation to perceived barriers (rs = −0.145) and conflict of interest (rs = −0.103).

The participants' oncology nursing experience had a weak positive correlation to self-efficacy (rs = 0.101), workplace safety climate

TABLE 3
Mean Calculations per Theoretical Predictor Variables; Survey Findings and Meaning

Variable Name	N	Mean	S.D	Observed	Possible	Survey findings	Meaning
Knowledge	675	10.4	1.37	4-12	0-12	Survey results indicate higher knowledge among nurses	Higher scores indicate higher knowledge
Self-efficacy	675	22.3	3.72	11-28	7-28	Survey results indicate higher self-efficacy among nurses	Higher scores indicate higher self-efficacy
Perceived barriers	675	20.3	5.62	13-43	13-52	Survey results indicate low perceived barriers among nurses	Higher scores indicate higher perceived barriers
Perceived risks	675	2.8	0.34	1.7-4	1-4	Survey results indicate moderate perceived risks among nurses	Higher scores indicate higher perceived risks of harm
Interpersonal influence	675	17.7	3.2	1-20	0-20	Survey results indicate high interpersonal influence	Higher scores indicate a more positive view of co-worker's attitude
Conflict of interest	675	8.96	3.05	6-18	6-24	Survey results indicate low conflict of interest amongst the nurses	Higher scores indicate a higher conflict of interest
Workplace safety climate	675	84.6	14.3	35-105	21-105	Survey results indicate a moderate safety climate in the workplace	Higher scores indicate a better safety climate
Total Safe Handling (Global)	602[a]	1.46[a]	0.94[a]	0-4.5	0-5	Survey results indicate low total safe handling precautions when administering and disposing of hazardous drugs	Higher scores indicate greater use of safe-handling precautions
Total Safe Handling (UK)	602[b]	3.36	0.62	1.33-5.0	0-5	Survey results indicate moderate total safe handling (UK) precautions when administering and disposing of hazardous drugs	Higher scores indicate greater use of safe-handling precautions

[a] Total participants administering and disposing of CDs.
HD precautions(Global): Total safe-handling precautions were measured using the 10 items for administration and disposal (CDs gloves, double gloves, CDs gowns, eye protection, and respirators/masks).
[b] Total participants administering and disposing of CDs.
HD precautions (UK): Total safe-handling precautions were. measured using the 6 items for administration and disposal (CDs gloves, other gloves and plastic aprons).

(rs = 0.120), and safe handling precaution score (rs = 0.086). The oncology nursing experience had a weak negative correlation to perceived barriers (rs = −0.138) and conflict of interest (rs = −0.082).

The participants' CD handling experience had a weak positive correlation to knowledge (rs = 0.101), self-efficacy (rs = 0.105), workplace safety climate (rs = 0.117), and total safe handling precaution score (rs = 0.081). CD handling experience had a weak negative correlation to perceived barriers (rs = −0.142) and conflict of interest (rs = −0.098). There was no correlation of theoretical predictors when compared with the number of patients treated by the nurses per day.

Relationship Between the Theoretical Predictor Variables

This section describes the bivariate correlations among the scores of the theoretical predictors using the Spearman rank-order test, with rs values and their significance (Table 5).

TABLE 4
Correlation Between Sample Characteristics and Theoretical PREDICTORS

Variable Name	Age (rs)	Years of nursing experience (rs)	Years of oncology experience (rs)	Years of chemotherapy experience (rs)	No of patients treated by the participant per day (rs)
Knowledge	0.093[a]	0.063	0.052	0.101[b]	−0.027
Self-efficacy	0.103[b]	0.133[b]	0.101[b]	0.105[b]	−0.014
Perceived barriers	−0.141[b]	−0.145[b]	−0.138[b]	−0.142[b]	0.040
Perceived risks	−0.111	−0.057	−0.019	−0.011	0.018
Interpersonal influence	0.068	0.040	0.009	0.001	0.071
Conflict of interest	−0.116[b]	−0.103[b]	−0.082[a]	-0.098[a]	−0.032
Workplace safety climate	0.156[b]	0.171[b]	0.120[b]	0.117[b]	−0.052
Total Safe Handling Precautions Global (N = 602) [c]	0.082[a]	0.085[a]	0.086[a]	0.081[a]	0.050
Total Safe Handling Precautions UK (N = 602)[c] 6 items	−0.013	−0.012	−0.010	−0.028	0.064
Total Safe Handling Precautions UK (N = 602) 13 items with Closed system	0.061	0.073	0.055	0.050	0.092[a]
Total Safe Handling Precautions UK (N = 602) 12 items without closed system	0.051	0.057	0.041	.035	0.112[b]

Spearman rank coefficient (rs).
[a] Correlation is significant at level $P < .05$.
[b] Correlation is significant at level $P < .01$.
[c] Total safe handling precautions are calculated for 602 participants who have both administered and disposed of the chemotherapy. (Ten items for Global and 6 items for UK).
Safe Handling 13 items (Closed system, chemotherapy gloves, other gloves, chemotherapy gowns, Plastic apron, eye protection, and respirators/masks) new UK scoring.
Safe Handling 12 items (chemotherapy gloves, other gloves, chemotherapy gowns, Plastic apron, eye protection, and respirators/masks) new UK scoring without Closed system.

TABLE 5
Correlation Between the Theoretical Predictors

Variable Name	Knowledge	Self-efficacy	Perceived barriers	Perceived risks	Interpersonal influence	Conflict of interest	Workplace safety climate
Self-efficacy	−0.044						
Perceived barriers	.032	−0.453[b]					
Perceived risks	−0.021	−0.335[b]	0.265[b]				
Interpersonal influence	−0.078[a]	0.242[b]	−0.381	−0.153[b]			
Conflict of interest	−0.014	−0.289[b]	0.514[b]	0.303[b]	−0.260[b]		
Workplace safety climate	−0.047	0.676[b]	−0.556[b]	−0.333[b]	0.301[b]	−0.400[b]	
Total safe handling precautions (Global) (N=602)[c] 10 items	−0.015	0.030	−0.043	−0.062	0.055	−0.024	0.007
Total safe handling precautions (UK) N=602[c] 6 items	−0.065	0.051	−0.051	−0.035	0.028	−0.001	0.070
Total safe handling precautions UK (N=602) 12 items and Closed System	−0.061	0.049	−0.077	−0.066	0.085[a]	−0.045	0.031
Total safe handling precautions UK (N=602) 12 items NO closed system	−0.077	0.056	−0.096[a]	−0.067	0.090[a]	−0.050	0.039

Spearman rank coefficient (rs).
[a] Correlation is significant at level $P < .05$.
[b] Correlation is significant at level $P < .01$
[c] Total safe handling precautions are calculated for 602 participants who have both administered and disposed of the CDs.
Safe Handling 13 items (Closed system, CDs gloves, other gloves, CDs gowns, Plastic apron, eye protection, and respirators/masks) new UK scoring
Safe Handling 12 items (CDs gloves, other gloves, CDs gowns, Plastic apron, eye protection, and respirators/masks) new UK scoring without Closed system.

The knowledge of hazards demonstrated a weak negative correlation with the interpersonal influence of nurses (rs = −0.078*). Rs Self-efficacy was negatively correlated with perceived barriers (rs = −0.453**) and perceived risks (rs = −0.335**). Conflict of interest exhibited a negative correlation with interpersonal influence (rs = −0.289**) but a positive correlation with workplace safety climate (rs = 0.676**).

Perceived barriers showed a positive correlation with perceived risks (rs = 0.265**) and conflict of interest (rs = 0.514**) but a negative correlation with self-efficacy (rs = −0.453**), interpersonal influence (rs = −0.381), and workplace safety climate (rs = −0.556**).

Perceived risks were negatively correlated with self-efficacy (rs = −0.335**), interpersonal influence (rs = −0.153), and workplace safety climate (rs = −0.333**) while positively correlated with conflict of interest (rs = 0.303**).

Interpersonal influence showed negative correlations with perceived barriers (rs = −0.381), perceived risks (rs = −0.153), conflict of interest (rs = −0.260**), and knowledge (rs = −0.078*), but positive correlations with self-efficacy (rs = 0.242**) and workplace safety climate (rs = 0.301**).

Conflict of interest was negatively correlated with self-efficacy (rs = −0.289**), interpersonal influence (rs = −0.260**), and workplace safety climate (rs = −0.400**) but positively correlated with perceived barriers (rs = 0.514**) and perceived risks (rs = 0.303**).

Workplace safety climate showed negative correlations with perceived barriers (rs = −0.556**), perceived risks (rs = −0.333**), and conflict of interest (rs = −0.400**), while positively correlated with self-efficacy (rs = 0.676**) and interpersonal influence (rs = 0.301**).

Finally, no significant correlation was found between the total safe handling precaution global scores, the UK scores, and any theoretical predictors.

The regression analysis (Table 6) indicated that several items positively predicted the safe handling precautions (Global), and some theoretical predictors negatively predicted the safe handling precautions of the nurses. The model was not statistically significant, Global (10 items) R2 = 0.010 (adjusted R2 = −0.003) F (0.744, $P > .05$); UK (6 items) R2 0.023 (adjusted R2 = 0.010) F (1.779, $P > .05$); and the UK (13 items) R2 0.023 (adjusted R2 = 0.020) F (1.497, $P > .05$), respectively. Statistical significance was observed in the perceived barriers and the number of patients handled per day with the UK (12 items) R2 0.027 (adjusted R2 = 0.014) F (2.063, $P < .05$).

Analysis of variance and post hoc testing demonstrated that the mean number of patients per day was significantly higher in government settings, F (15.807, 74), $P < .001$ compared to the private clinics. The safe handling scores (Global) obtained by the nurses were also compared between the government and private clinics (76 data matched private and NHS nurses); it was found there was a significant difference with a p-value of $P = .04 < .05$.

The safe handling scores (UK) obtained by the government nurses were better than those obtained by the private clinics since the private clinics followed more of the global guidelines with PPE. Although the results were significant, they indicate that the safe handling scores (UK) in private clinics are unjustified since plastic aprons and other gloves were not used in private clinics, and they used other PPE following the global guidelines.

Discussion

Overall, this UK sample of oncology nurses administering and handling CDs were knowledgeable about hazards and confident in their ability to practice safe handling; they perceived fewer barriers and moderate perceived risks. They perceived fewer conflicts of interest and a moderate workplace safety climate. However, this was for CDs as part of the SACT regimen. The survey's open-ended comments identified that nurses felt they have a potential handle on the administration of CDs but, in comparison, are anxious about the overall safety of preparing novel [MABs] drugs, identified as hazardous, with unknown risk profiles.[2] Furthermore, this survey has identified that oncology nurses perceive that they are preparing drugs with limited guidance, with the quotes identifying this as MABs (Table 7), whilst CDs are pre-prepared for administration (Table 3).

When looking at the current use of PPE for CDs, due to the lack of UK guidance for safe handling precautions, it was necessary to analyses the data against four different potential safe handling precautions detailed in Tables 4 and 5. When comparing the global, ten-item guidance determined by Polovich and Clarke,[20] there appeared to be an association of safe handling precautions among the older and more experienced SACT administrators. The study results show a similar pattern to seven other studies that reported significant correlations when comparing demographical factors such as education, age, and work experience.[28,29,31-36] Four other studies compared the demography and reported no significant differences.[20,23,24,37]

TABLE 6
Regression Analysis for Safe Handling Precautions (Global scores and UK scores) among Nurses

Predictors (Total Safe Handling Global scores) 10 items	Standardized coefficients β	95% confidence interval	
		Lower bound	Upper bound
Knowledge	0.010	−0.048	.061
Self-efficacy	−0.007	−0.030	.026
Perceived Barriers	−0.056	−0.027	.009
Perceived Risks	−0.047	−0.052	.016
Interpersonal Influence	0.024	−0.018	.032
Conflict of interest	0.019	−0.024	.036
Safety climate	−0.029	−0.009	.006
Patients treated per day	0.067	−0.001	.013
R2=0.010 (adjusted R2= −0.003) F (0.744, P>0.05)			
Predictors (Total Safe Handling UK scores) 6 items	**Standardized coefficients β**	**95% confidence interval**	
		Lower bound	**Upper bound**
Knowledge	−0.083	−0.073	−0.002
Self-efficacy	−0.005	−0.019	0.017
Perceived Barriers	−0.074	−0.020	0.004
Perceived Risks	0.001	−0.022	0.023
Interpersonal Influence	0.026	−0.011	0.021
Conflict of interest	0.124	0.005	0.045
Safety climate	0.059	−0.002	0.008
Patients treated per day	0.032	−0.003	0.007
R2=0.023 (adjusted R2= 0.010) F (1.779, P>0.05)			
Predictors (Total Safe Handling Global scores) 13 items	**Standardized coefficients β**	**95% confidence interval**	
		Lower bound	**Upper bound**
Knowledge	−0.029	−0.051	0.024
Self-efficacy	0.019	−0.016	0.023
Perceived Barriers	−0.090	−0.023	0.002
Perceived Risks	−0.048	−0.036	0.011
Interpersonal Influence	0.065	−0.004	0.030
Conflict of interest	0.041	−0.012	0.030
Safety climate	−0.053	−0.008	0.003
Patients treated per day	0.063	−0.001	0.009
R2=0.020 (adjusted R2= .007) F(1.497, P>0.05)			
Predictors (Total Safe Handling UK scores) 12 items	**Standardized coefficients β**	**95% confidence interval**	
		Lower bound	**Upper bound**
Knowledge	−0.048	−0.062	0.016
Self-efficacy	0.003	−0.019	0.020
Perceived Barriers	−0.116	−0.027	−0.001
Perceived Risks	−0.042	−0.036	0.013
Interpersonal Influence	0.053	−0.007	0.029
Conflict of interest	0.051	−0.010	0.033
Safety climate	−0.46	−0.008	0.003
Patients treated per day	0.094	0.001	0.011

R2=0.027 (adjusted R2= 0.014) F (2.063, $P < .05$).
Significance in perceived barriers and patients treated per day.

TABLE 7
Qualitative Data From the Open-Ended Survey: Quotes About Novel Treatments

Qualitative data from the open-ended survey: Quotes about novel treatments
• Examples of individual responses include the preparation of MABs from the open-ended question: Would you like to state anything else:
• "Currently looking at the potential risks of preparation immunotherapies/ MABs - currently prepared in small clinical, non-aseptic areas without the use of CSTDs - looking for evidence to support the implementation of these devices to protect our staff; minimize exposure and needle stick injuries."
• "In recent 1 year - 4 accidents with preparing MABS (splashes and needlestick injuries) in the [government] setting I treated many more patients per day, and it was often very crowded, and the private sector is very quiet in comparison. [government] units are in my experience usually understaffed."
• "We are expected to prepare [Mabs] on the ward with minimal protective equipment."
• "We only use closed systems for preparing [MABS] and not administering. Lots of push back from management about the cost of closed systems."
• "We do prepare some mabs using closed systems."
• "We have recently just bought closed systems into place. We prepare [MABS] and aseptic prepare CDs."
• "The [organization] I work for administers SACT as well as [MABs] for purposes other than cancer treatment. My role as [oncology nurse] is to provide the team with knowledge and understanding of SACT and its hazards as this has previously been overlooked. . .. The [organization] is not on board with the use of closed systems due to the cost in comparison how few of the drugs we deliver are actually cytotoxic. Regarding PPE, eye protection is not compulsory, and shoe protection is not part of the spill kit. I have a long way to go to ensure the team are educated and best practice is adhered to."

In the UK's governmental hospitals, the guidance on safe handling precautions is vague; however, this study has indirectly identified that the primary PPE provision is a *plastic apron with CD gloves*. The safe handling precautions for the UK PPE provision were not associated with nursing characteristics or any predictor factors. When combining the safe handling precautions, with or without CSTDs, there was an association with higher safety precautions, fewer perceived barriers, and a great sense of interpersonal influence. However, there was no association with creating a workplace safety climate. Therefore, the organization, resources, and guidance are crucial to adopting standard PPE directed by an organization.

Although there is a presumed indirect standardization of PPE practice in the UK, there is variation in the use of CSTDs for administration across the private and governmental sectors.[38] The average use of CSTDs is higher for preparation than administration, although this falls short of implementing CSTDs for all preparations. Masks and eye protection are being utilized in preparation, but more worryingly, there is little use of biosafety cabinets used for preparation. Closed systems are now advocated for both preparations and administration of hazardous cytotoxic and cytostatic drugs.[39]

Self-efficacy and interpersonal influence in our study were reported to be high, consistent with findings by Callahan et al. (2016)[22] and Polovich and Clark (2012).[20] In this study, greater confidence in using PPE was linked to a reduced perception of barriers to its use and stronger trust in co-workers, contributing to an overall positive perception of the workplace safety climate. Self-efficacy and confidence are not associated with knowledge of the individual or translate into safe-handling precautions. This association may be because the overall knowledge of hazard and safe-handling precautions identified for the UK were consistently high, or that knowledge does not translate into confidence in using PPE. However, knowledge is associated with fewer issues with co-workers and potentially 'trust'. This trust is an ability to position oneself 's practice with co-workers or challenge co-workers if they are non-adherent. Being able to whistle blow has been identified as integral to practice.[40]

Six studies highlighted that a better workplace-safe climate improved the usage of PPE.[20,22,18,29,34,36] However, this was not the case in our study. *Workplace safety climate* overall was identified as moderate in this study, and there may be complex reasons why this needs to be explored further. A systematic review[41] identified long working hours, high workloads, lower pay, and lack of overtime payments leading to burnout and emotional disturbances among nurses, which are linked to various adverse outcomes in healthcare, including worker errors and injuries. Workplace safety also included a lack of training, cost-cutting measures, and inadequate PPE. The review also identifies environmental factors such as insufficient ventilation, lighting, and noise reduction.[41] One factor identified in this study is the number of patients per nurse participant, and their practicing units are far higher than reported in other studies,[22-29] suggesting a high volume of patients and associated workload. This workload insight shows similar reporting to a recent study by Bao et al.,[42] which builds on the inherent complexity of the oncology nursing role, which is associated closely with an increasing number of patients and the complexity of novel treatments.

Understanding this complexity is crucial as we adopt the practice of preparing novel drugs within clinical practice. Firstly, there is no

national guidance or education to inform staff about potential health hazards. Therefore, the staff may appear confident in their practice without having the appropriate knowledge to support their confidence.

As confidence is associated with increased age and CD experience, this study needs to investigate further knowledge with confidence in the younger, newly qualified, and less experienced oncology nurses. It also needs to understand if the knowledge of hazards of CD-experienced individuals translates into safe-handling precautions required when handling novel drugs.

In addition, even though PPE is not at a global standard, most of the units administering CDs adhere to the UK level. The UK standard, however, is not practiced at the advised global level for maximum protection to prevent potential occupational exposure. As novel treatments are being developed and implemented in practice, there is a requirement to revisit the UK PPE requirements, especially in light of more preparation seemingly being conducted in the administrating units in conjunction with the increasing associated workload, which has a cascade effect on the safe handling precautions of cytotoxic drugs.

Future research must understand the extent and safe handling precautions for the novel therapies prepared in the SACT units. Furthermore, the safe handling precautions must be formalized and standardized in anticipation of the increase in the implementation of novel treatments requiring novel administration routes and the growing cancer populations requiring treatment.

Strengths and Limitations

The model in regression analysis did not have statistical significance due to several factors, such as the sample size and the relationship between the variables being more complex than the linear and the independent variables, which do not influence the safe handling precaution scores of nurses. Initially, the analysis was associated with global PPE requirement, which was not necessarily the correct variable to assess in the UK. The data analysis was further complicated by the independent sector and governmental differences within the UK, making it difficult to compare the UK's overall data globally. Additionally, the survey collected data at a regional level to preserve anonymity, meaning information on the size or location of SACT units was not available for analysis. Future research may explore a much larger sample size and alternative statistical methods and include all SACT administration and disposal variables.

Conclusion

This survey, conducted across the UK, highlighted different private and governmental practices regarding PPE requirements and patient workload. The survey indirectly identified a minimum standard of PPE requirement for administering and disposing of CDs. This survey has also indirectly identified that units are preparing SACT drugs (i.e. novel treatments), with an inconsistent utilization of biosafety cabinets and CSTDs, eye protection and masks. Overall, the UK has a moderate workplace safety climate, partially supported by an individual's self-efficacy and co-worker trust. However, the complexity could also be associated with high patient volume and workload. None of the predictive factors translated into safe handling practices except co-worker trust. There is an indication that participants felt knowledgeable about the hazards of administering SACT but were unclear and anxious about the implementation of preparing and administration of novel drugs in light of limited guidance and standardization of PPE.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Karen campbell reports financial support was provided by UK Oncology Nursing Society. Karen campbell reports a relationship with UK Oncology Nursing Society that includes: board membership. I am currently on the editorial board for seminar in oncology nursing If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Karen Campbell: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Daniel Dicksit:** Writing – original draft, Validation, Project administration, Investigation, Formal analysis, Data curation. **Martha Polovich:** Writing – review & editing, Conceptualization.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Grammarly in order to identify grammatical errors. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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