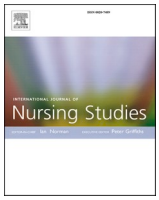
International Journal of Nursing Studies 160 (2024) 104907

Contents lists available at ScienceDirect

International Journal of Nursing Studies

journal homepage: www.elsevier.com/locate/ns



Knowledge and safe handling practices affecting the occupational exposure of nurses and midwives to hazardous drugs: A mixed methods systematic review

Pheona van Huizen [a,*], Philip L. Russo [a,b,d], Elizabeth Manias [a], Lisa Kuhn [c], Clifford J. Connell [a]

[a] Monash Nursing and Midwifery, Monash University, Australia
[b] Cabrini Research, Cabrini Health, Australia
[c] School of Nursing, Midwifery and Paramedicine, Australian Catholic University, Australia
[d] School of Nursing and Health, Avondale University, Australia

ARTICLE INFO

Keywords:
Hazardous substances
Nurses
Occupational exposure
Pender health promotion model
Prevention and control
Risk management

ABSTRACT

Background: Hazardous drugs are inherently toxic and present a potential occupational exposure risk to nurses and midwives. Hazardous drugs require special handling to minimise the risk of exposure and adverse health effects. Although the use of hazardous drugs in oncology services is well recognised, they are also used in other healthcare areas where nurses and midwives may be unaware there is a risk.
Objective: To investigate what nurses and midwives know and do about their occupational exposure to hazardous drugs, and what factors affect their knowledge and practice.
Design: Mixed methods systematic review.
Methods: A systematic review was conducted, and studies were included if the authors described what nurses or midwives knew about hazardous drugs, or what they did in their clinical practice to reduce their risk of occupational exposure (PROSPERO registration CRD42024437493). The databases were searched for any year until the 26th of January 2024.Two independent reviewers extracted data using Covidence and assessed the risk of bias. The data were extracted into the categories of knowledge of risk and safe handling practices, attitude and factors affecting these, and activities that posed the greatest risk of exposure (preparation, administration, and disposal of hazardous drugs, cleaning hazardous drug spills, and handling excreta from patients who had recently been treated with hazardous drugs).
Results: Of the 2702 articles that were identified, 59 quantitative and 3 qualitative studies were included in this review. No studies reported on midwives handling hazardous drugs. Most studies investigated nurses working in oncology services. Nurses reported a lack of education about the risk and safe handling. They were often responsible for preparing hazardous drugs and there was inconsistency in their compliance when using personal protective equipment. Nurses did not always perceive that there was a real risk of exposure, were concerned about the effect of wearing personal protective equipment on their relationship with patients and perceived they lacked the time to don equipment.
Conclusions: The risk of occupational exposure to hazardous drugs outside of oncology services was rarely investigated. There were no studies reporting what midwives knew and did about their risk of occupational exposure to hazardous drugs. When nurses were aware of the risks, this did not necessarily translate into the implementation of safe handling practices or the consistent use of personal protective equipment because of a perceived low risk, lack of personal protective equipment availability, and prioritising personal or patient comfort over safety measures.
Tweetable abstract: Nurses and midwives are often unknowingly exposed to the toxic effects of hazardous drugs when they prepare and administer these drugs for patients, although knowledge does not always equal safe handling practices.

* Corresponding author at: Monash University, School of Nursing and Midwifery, 35 Rainforest Walk, Clayton, VIC 3168, Australia.
E-mail address: pheona.vanhuizen@monash.edu (P. van Huizen).
@PLR_aus (P.L. Russo), @emanias1 (E. Manias), @lisajkuhn (L. Kuhn), @cliffconnell (C.J. Connell)

https://doi.org/10.1016/j.ijnurstu.2024.104907
Received 25 March 2024; Received in revised form 5 September 2024; Accepted 6 September 2024
Available online 12 September 2024

What is already known

- Oncology nurses do not always implement safe-handling practices for hazardous drugs, even when they know about the risk of occupational exposure
- A positive workplace safety climate is associated with a higher level of personal protective equipment use

What this paper adds

- No studies were found investigating midwives' knowledge and safe handling practices related to hazardous drugs
- Despite guidelines recommending pharmacists prepare cytotoxic drugs in a controlled environment, nurses are still preparing these hazardous drugs
- A significant research gap exists regarding evidence on nurses' and midwives' knowledge and safe handling of non-cytotoxic hazardous drugs, with virtually nothing known

1. Background

Hazardous drugs are inherently toxic and pose an occupational exposure risk for nurses and midwives. These drugs have been linked to one or more of the following: cancer, teratogenesis, reproductive issues, genetic damage and end-organ damage (e.g., to skin, kidneys, liver, bladder) (National Institute for Occupational Safety and Health, 2023). Although most people associate hazardous drugs with cancer treatments, hazardous drugs are a subset of medications that are regularly prescribed to treat various medical conditions and many nurses and midwives remain unaware that the drugs they handle in other healthcare areas are classified as hazardous (Batista et al., 2021; Polovich, 2020; Spader, 2007; Fuller et al., 2007). Furthermore, patients treated in oncology services can be prescribed hazardous drugs for medical conditions unrelated to their cancer. For instance, fluconazole, an antifungal agent used to treat oral candidiasis (thrush) (Therapeutic Guidelines Limited, 2023a) and oesophageal candidiasis (Therapeutic Guidelines Limited, 2023b), can pose a reproductive risk for nurses and midwives. Drugs classified as hazardous include aminoglycosides, angiotensin-converting enzyme inhibitors, angiotensin II receptor antagonists, antiepileptics, antifungals, antivirals, statins (except pravastatin), immunosuppressants and oestrogens (Victorian Therapeutics Advisory Group, 2021; National Institute for Occupational Safety and Health, 2020).

Given the widespread use of hazardous drugs across various healthcare settings, understanding the potential exposure risk is crucial for nurses and midwives. Nurses and midwives commonly prepare and administer prescribed medications, including hazardous drugs, in a variety of settings including hospitals, clinics, residential care facilities and in patients' homes (Lee et al., 2007; Martin and Larson, 2003; Forough et al., 2020; Eisenberg and Klein, 2021). Occupational exposure can occur when these drugs become aerosolised, create dust, leak or splash during handling, including when handling bodily fluids, which can lead to inhalation, dermal or mucosal absorption, or ingestion (National Institute for Occupational Safety and Health, 2023). These circumstances put nurses and midwives at risk of exposure every day when they care for patients.

A recent systematic review reported that up to 55 % of hospital personnel involved in handling hazardous drugs had traces of the investigated drugs present in their urine samples, indicating exposure had occurred (Leso et al., 2022). The potential for exposure is not limited to individual handling practices; nurses, midwives, and other people working or residing in areas where hazardous drugs are prepared or administered are at risk if the environment becomes contaminated (Broto et al., 2017; ISOPP Standards Committee, 2022). However, directly correlating this exposure with acute and long term health outcomes is challenging, especially since health monitoring, when conducted, cannot differentiate between effects from occupational exposure to hazardous drugs and exposure to other toxins outside the workplace (Gallant, 2008). Infections directly related to treatments, such as with the immunostimulant Bacillus Calmette-Guérin, are exceptions (Marx et al., 2023; Cancer Institute NSW, 2024).

To mitigate occupational exposure in workplaces, protective measures commonly follow the hierarchy of controls framework, which employs a top-down methodology. This hierarchy comprises five levels for controlling risks and serves as a framework for risk management guidelines (Fig. 1). Healthcare policymakers can implement evidence-based control measures at each level to reduce the risk of people being exposed to hazardous drugs (Gruenewald and Gilkey, 2021; National Institute for Occupational Safety and Health, 2023).

The use of personal protective equipment is the bottom level of the hierarchy of controls and is often perceived as the most crucial aspect of risk reduction when a bottom-up approach is used. While personal protective equipment is absolutely necessary, its use can be time-consuming, resource intensive, and relies on individual compliance (Lawson et al., 2019; Benoist et al., 2022a). Furthermore, the risk of exposure persists when a healthcare environment is contaminated, and personal protective equipment is not in use. Higher level controls can be more effective at reducing the overall risk (National Institute for Occupational Safety and Health, 2023; Morris and Cannady, 2019). However, if the risk is unknown or ignored, no controls, including the use of personal protective equipment, may be implemented in healthcare settings (Fazel et al., 2022).

While previous systematic and integrative literature reviews have examined guidelines, factors influencing the exposure of nurses, educational interventions, knowledge gaps, and health risks related to handling hazardous drugs (Leso et al., 2022; Bernabeu-Martínez et al., 2018; Abu-Alhaija et al., 2023; Banihani et al., 2022; Coyne et al., 2019; Hon et al., 2014; Dranitsaris et al., 2005), these reviews focused on oncology nurses or healthcare workers handling chemotherapy, cytotoxic or antineoplastic drugs. None of the existing reviews comprehensively addressed the broader category of hazardous drugs or included the discipline of midwifery. Therefore, to address this gap, the research question for this systematic review was 'What do nurses and midwives know and do about their occupational exposure to hazardous drugs, and what factors affect their knowledge and practice?'

2. Methods

This systematic review was conducted based on a protocol registered with the International Prospective Register of Systematic Reviews (PROSPERO registration CRD42024437493). The 'Preferred Reporting

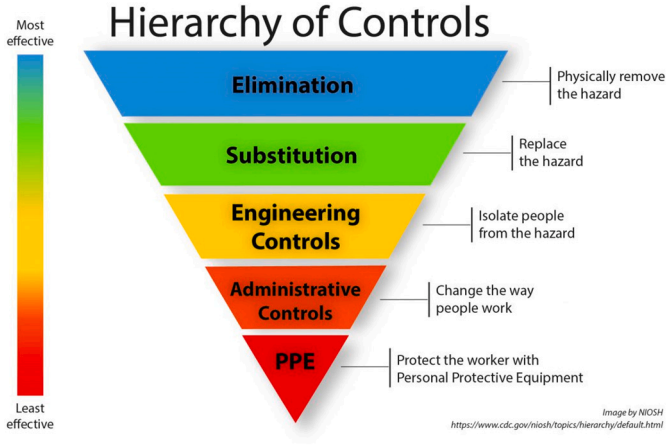


Fig. 1. The hierarchy of controls for controlling exposure to occupational hazards (National Institute for Occupational Safety and Health, 2022) (Public domain).

Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement' has been used for reporting (Page et al., 2021). The screening and data extraction stages of the data management were conducted using Covidence (Veritas Health Innovation) and Excel (Microsoft Corporation) software.

The study selection was based on the Population, Phenomenon of interest, Context (PICo) framework for developing a research question (Table 1) (Lockwood et al., 2015). This systematic review included the population of nurses and midwives because both these groups of healthcare professionals can be responsible for the preparation and administration of medications for patients. The phenomenon of interest was medications that fit the broader internationally accepted National Institute for Occupational Safety and Health (NIOSH) definition of hazardous drugs, where there is a risk of occupational exposure, not just drugs that are classified as antineoplastic, cytotoxic or chemotherapy (National Institute for Occupational Safety and Health, 2023).

2.1. Search strategy

The search terms were piloted and refined whilst working with a specialty librarian. The search strategy was tested to ensure that it captured key articles found during the preliminary hand searching for relevant data.

2.2. Eligibility criteria

Primary research studies were included if the authors investigated nurses' and/or midwives' knowledge about hazardous drugs, what nurses and/or midwives did in clinical practice to reduce their risk of occupational exposure, or any attitudes or factors that were reported to affect knowledge or practice. Data describing the handling of any hazardous drug, for any clinical indication, in any healthcare setting were included. Studies from any year, and studies in English or studies that had been translated into English, and met the eligibility criteria, were considered for inclusion.

Studies were excluded if they reported solely on health effects, the biomonitoring of nurses or midwives and surface or environment contamination. Studies were also excluded if it was not clear which data were associated exclusively with nurses and/or midwives. Primary research of any design was included, including theses or dissertations, but not reviews, reports about studies, abstracts or conference proceedings, or posters.

2.3. Information sources

The final search of the databases CINAHL Complete (EBSCOhost), Embase classic + Embase (Ovid), Emcare (Ovid), MEDLINE (R) (Ovid), International Pharmaceutical abstracts (ProQuest) and PsycINFO (APA PsycNET) was conducted on the 26th of January 2024. The databases searched, search terms used, strategy and results for the database searches are provided in Supplementary file 1.

References were saved into EndNote (Clarivate analytics) after each of the six individual database searches, and then imported into Covidence where duplicate studies were removed. The title and abstract, and then the full texts were screened independently in duplicate (PV and PR, EM, LK or CC) to determine if they met the inclusion criteria. The review was blinded using the Covidence software. Any disagreements about inclusion were resolved through discussion with all authors to reach consensus. This process is outlined in Fig. 2

Table 1
The PICo framework.

Population	Phenomenon of interest	Context
Nurses or midwives who prepare and/or administer drugs: • Nurse Practitioner • Registered nurse • Registered midwife • Medication endorsed enrolled nurse • Certified Midwife • Certified Nurse-Midwife	Hazardous drugs as defined by the National Institute for Occupational Safety and Health (NIOSH). Handling activities including preparation, administration, disposal of equipment and unused drug portions, spill management, and handling bodily fluids	Knowledge of the risk, knowledge of and the actual use of safe handling practices including recommended personal protective equipment, and attitudes or factors that affect knowledge and practice

2.4. Data extraction

A unique data extraction template was created in Covidence, including the risk of bias assessment, and piloted by the researchers. The template was edited using the researchers' feedback from the pilot to resolve any inconsistencies and to add explanations to ensure all reviewers were clear about what data to extract to answer the research question (Supplementary file 2). The data extraction and the risk of bias assessment was also completed independently by two researchers (PV and PR, EM, LK or CC) and a third researcher completed the consensus.

During data extraction, further studies were excluded when they were found not to meet the inclusion criteria because nurses' or midwives' data were not disaggregated from other healthcare workers, as shown in Fig. 2. Data was sought from corresponding authors if they were not reported in the article and were not available as a supplementary file (Hon et al., 2015; Srisintorn et al., 2021). The reference lists of all included studies were reviewed for citations that may be relevant for inclusion. Titles were added into the assigned data extraction template field, then the first author added these studies to Covidence for blinded duplicate full-text review.

2.5. Risk of bias assessment

The 'Appraisal tool for Cross-Sectional Studies' was used to assess study design, reporting quality and the risk of bias in the cross-sectional quantitative studies, the 'Critical Appraisal Skills Programme (CASP) Randomised Controlled Trial Standard Checklist' was used for the experimental studies and the 'CASP Qualitative Studies Checklist' was used for the qualitative studies (Downes et al., 2016; Critical Appraisal Skills Programme, 2021b; Critical Appraisal Skills Programme, 2021a). The 'Appraisal tool for Cross-Sectional Studies' and 'Critical Appraisal Skills Programme' tools did not provide an overall numerical rating for the quality of the studies and the checklists were not linear in the weighting of each item, therefore the overall quality rating was based on the individual aspects of each study (Downes et al., 2016). The risk of bias assessments are shown in Tables 3, 4 and 5.

2.6. Synthesis

The quantitative and qualitative data were synthesised using an aggregative approach by categorising data according to each component of the research question to converge the data (Ferguson et al., 2020). The categories to capture what nurses and midwives knew were: knowledge of the risk, policies and guidelines, education or professional development, and attitude or factors affecting knowledge and practice. Preparation, administration, disposal, spills management, handling bodily fluids (from patients who had recently been treated with hazardous drugs) and overall handing (when data were not differentiated into an activity) were the categories for what nurses and midwives did.

3. Results

3.1. Study characteristics

The review process identified and included 62 studies for data

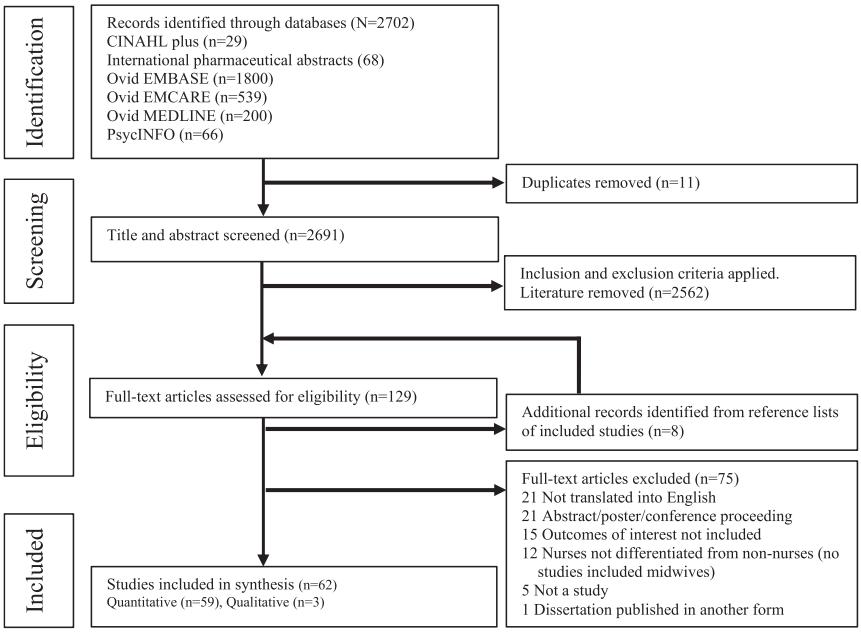


Fig. 2. Adapted from Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram template for systematic reviews (Page et al., 2021).

analysis out of an initial 2702 records, as shown in Fig. 2. The data included fifty-nine quantitative studies, of which one was a dissertation, and three qualitative studies. Most of the studies were from North America (n = 26) or Asia (n = 25), five were from Europe, three from Africa, one each from the United Kingdom and South America, and one study stated it was International. The studies were included regardless of the methodological quality evaluated in the risk of bias assessments (Tables 3, 4 and 5). The risk of bias assessments illustrated that most of the studies did not explain or justify the sample size and few reported information about non-participants.

No studies reported on what midwives know and do about their risk of occupational exposure to hazardous drugs. The studies summarised in Table 2 were almost exclusively from populations referred to as oncology or chemotherapy nurses and reported on a subset of hazardous drugs described by various terms such as antineoplastic, cytotoxic, chemotherapy or antitumour (n = 61). Only one study used the broader hazardous drug term and was not exclusively from an oncology setting (Fuller et al., 2007).

The quantitative studies predominately utilised a self-administered or interviewer-completed questionnaires (n = 58). In contrast, the doctoral dissertation employed an observational tool as the sole data collection method (Brink, 2016).

3.2. What nurses know

3.2.1. Policies and guidelines

Many researchers reported that workplace policies and guidelines on handling hazardous drugs were either unavailable or unfamiliar to nurses (Table 2). Even when guidelines existed, nurses reported not always complying with them (Baykal et al., 2009; Topcu and Beser, 2017). The most referenced guidelines were from the American Society of Health-System Pharmacists (ASHP), Oncology Nursing Society (ONS), National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA).

3.2.2. Education and professional development

The percentage of nurses who had received any education specific to handling hazardous drugs ranged widely, from 0 % (Chaudhary and Karn, 2012) to 96 % (Callahan et al., 2016; DeJoy et al., 2017; Walton et al., 2020). When reported, at least 25 % of nurses had received education and training more than twelve months prior to the study (Table 2). Six studies described the implementation of different educational interventions, including a 30-min video, a one-hour online module, a pharmacist-led intervention, a two-day workshop, 12 h of delivered lectures and practice sessions, and content provided via a mobile phone application (Table 2). Across all these intervention studies, it was reported that nurses' knowledge of hazardous drug risks improved after the educational initiatives.

3.2.3. Knowledge of the risk

Nurses' knowledge about occupational exposure risk, the importance of personal protective equipment, and the actual hazard were assessed using various questionnaires, with the most common being adaptations of the 'Hazardous Drug Handling Questionnaire' (Polovich and Clark, 2012); the original 'Chemotherapy Handling Questionnaire' was developed by Martin and Larson (2003), revised to become the 'Hazardous Drug Handling Questionnaire' by Polovich and Martin (2011) and further revised by Polovich and Clark (2012). While knowledge levels varied, researchers reported that nurses had a general lack of awareness about the risk (Table 2).

3.3. What nurses do

3.3.1. Preparation

Studies from almost all countries reported nurses' involvement in the preparation of hazardous drugs; pharmacy staff were solely responsible for preparation in four studies (Graeve et al., 2017; Srisintorn et al., 2021; Chen et al., 2016; Colvin et al., 2016). It was reported that in Iran and Turkey it was legislated that it was the responsibility of nurses to prepare medications, which included hazardous drugs (Abbasi et al., 2016; Baykal et al., 2009). When nurses prepared hazardous drugs their self-reported practice of wearing personal protective equipment was not in accordance with guidelines, except in one study where 100 % of nurses reported they usually wore gloves (Polovich and Martin, 2011). The reported use of biological safety cabinets varied from 0 % (Chaudhary and Karn, 2012; Rogers, 1987) to 100 % (Orujlu et al., 2016; Martin and Larson, 2003; Momeni et al., 2013), although when biological safety cabinets were always used, they were sometimes not

Table 2
What nurses know and do about their occupational exposure to hazardous drugs, and what factors affect their knowledge and practice.

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
Cross-sectional and cohort studies					
Abbasi et al., 2016 (Iran)[a]	To determine the occupational protection status of clinical nursing staff exposed to cytotoxic drugs and the range of skin and mucosal contamination with cytotoxic drugs	Cross-sectional study Self-administered questionnaire (newly developed) and checklist (adapted from Hazrati et al., 2008)	N = 86 oncology nurses; n = 57 inpatient and n = 29 outpatient N = 6 centres of chemotherapy Population nurses 130, response rate 66 %. There were 2 observations of each nurse's practice	Policies and guidelines No clear guidelines for safe handling of cytotoxic drugs during pregnancy and lactation. Education and professional development 8 (9 %) completed a short course before working in oncology 86 (100 %) desired to learn about safety standards with cytotoxic agents International Labor Organization recommendation that employees need to have knowledge and abilities appropriate for their working area	**Preparation** Questionnaire 86 (100 %) prepared cytotoxic drugs 15 (17 %) in open space Legislation that drugs are prepared by nurses 6 (100 %) chemotherapy centres had biological safety cabinet Class I available Checklist Mean of 2 observations of each nurse 46 (53 %) wore double gloves 65 (76 %) wore gown 46 (54 %) wore goggles 36 (43 %) wore mask Administration Checklist Mean of 2 observations of each nurse 1 (1 %) wore double gloves 4 (5 %) wore gown 2 (2 %) wore goggles 2 (2 %) wore mask Disposal Disposed of wastes together with other medical waste Checklist Mean of 2 observations of each nurse 3 (3 %) wore double gloves 5 (6 %) wore gown 2 (2 %) wore goggles 5 (5 %) wore mask Spill management 56 (65 %) had skin or mucosal exposure No emergency spill kits available Overall handling (not differentiated into activity) Pregnant nurses did not prepare cytotoxic drugs but administered and disposed of these drugs Checklist (total 50 = 25 preparation +12 administration +13 disposal) Outpatient nurses Mean 17.2 (± 2.52) (0–50) Inpatient nurses Mean 23.35 (± 3.02) (0–50)
Abu Sharour et al., 2021 (Jordan)[a]	To determine the predictors of practicing safe chemotherapeutic precautions among oncology nurses and to determine their level of knowledge pertaining to these practices	Cross-sectional study Self-administered 'Chemotherapy handling questionnaire' (Polovich and Clark, 2012), questions and results in study	N = 153 oncology nurses; inpatient. Population nurses 180, response rate 85 %	Education and professional development 51 (33 %) certified for chemotherapy administration Knowledge of the risk Mean 3.55 (± 2.09) (0–12) Attitude or factor affecting knowledge and practice Self-efficacy for using personal protective equipment Mean 19.56 (± 2.98) (6–24) Perceived barriers to using personal protective equipment Mean 28.20 (± 9.82) (13–52) Perceived risk Mean 3.21 (± 0.61) (1–4) Interpersonal influence	Overall handling (not differentiated into activity) 141 (92 %) wore double gloves 44 (29 %) wore gown 31 (20 %) wore eye protection 112 (73 %) wore mask

(continued on next page)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Mean 13.95 (± 3.00) (0–14) Conflict of interest Mean 15.86 (± 3.53) (6–24) Workplace safety climate Mean 80.31 (± 13.17) (21–105)	
Al-Azzam et al., 2015 (Jordan)[a]	To evaluate the compliance of healthcare workers in Jordanian hospitals with standard safety guidelines during the preparation and administration of antineoplastic medications	Cross-sectional study Interviewer-administered questionnaire (newly developed)	N = 252 healthcare workers prepare and administer chemotherapy; n = 206 nurses, n = 71 pharmacists, n = 5 pharmacy technicians; n = 15 hospitals. Population of 300 healthcare workers, response rate 84 % The nurses' data is reported here	Policies and guidelines Hospitals n = 15 15 (100 %) of hospitals had policies and procedures (cited National Institute for Occupational Safety and Health (NIOSH), American Society of Health-System Pharmacists (ASHP), International Society of Oncology Pharmacy Practitioners (ISOPP), Oncology Nursing Society (ONS), American Society of Clinical Oncology (ASCO) & Occupational Safety and Health Administration (OSHA) as international safe handling guidelines) Education and professional development 131 (64 %) had training program on handling chemotherapy medications	Preparation 9 (60 %) hospitals (n = 15) had biological safety cabinet 121 (59 %) used biological safety cabinet 151 (73 %) used close system device 180 (85 %) label medications Spill management Hospitals n = 15 13 (87 %) hospitals had a spill policy 12 (80 %) hospitals had a spill kit Overall handling (not differentiated into activity) 155 (75 %) perform hand hygiene 159 (77 %) not eating or drinking in working area 201 (98 %) wore double gloves 179 (87 %) wore gown 68 (33 %) wore googles 185 (90 %) wore mask 14 (7 %) wore shoe cover 43 (21 %) wore hair cover
Alehashem and Baniasadi, 2018 (Iran)	To evaluate the knowledge, attitude, and practice (KAP) of oncology nurses towards the safe handling of antineoplastic drugs and determine the educational needs for the promotion of safe behaviours	Cross-sectional study Self-administered questionnaire (newly developed), questions and results reported	N = 80 oncology nurses; inpatient. Population of nurses from six university hospitals	Education and professional development 59 (74 %) oncology trained 35 (44 %) had ongoing training Knowledge of the risk Mean 54.30 (± 10.86) (13–65) Attitude or factor affecting knowledge and practice Attitude Mean 32.83 (± 5.88) (8–40)	Preparation 77 (96 %) in preparation room 76 (95 %) prepared antineoplastic drugs in biological safety cabinet 75 (94 %) never did risky behaviour (eat, drink, smoke) in preparation room 74 (93 %) used personal protective equipment Administration 66 (83 %) used personal protective equipment Spill management 63 (79 %) managed accidents in handling based on standard protocols 75 (94 %) recorded and reported all accidents in handling of antineoplastic drugs Overall handling (not differentiated into activity) Practice Mean 50.35 (± 10.21) (12–60)
Asefa et al., 2021 (Ethiopia)[a]	To assess knowledge and practices on the safe handling of cytotoxic drugs among nurses working in the oncology unit at tertiary teaching hospitals in Addis Ababa, Ethiopia	Cross-sectional study Self-administered questionnaire (adapted from literature), questions and results reported	N = 77 oncology nurses; inpatient with at least one year experience. Population of nurses from the two government hospitals where cytotoxic drugs were administered	Education and professional development 26 (31 %) had chemotherapy training Knowledge of the risk Mean 7.80 (± 2.20) (0–15)	Preparation 42 (55 %) used vertical biological safety cabinet 13 (17 %) at nursing station 8 (10 %) at patient's bedside 2 (3 %) drank coffee in preparation area Administration 19 (25 %) always wore protective clothing changing intravenous fluids 23 (30 %) used needles as venting devices in

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					intravenous bottles 17 (22 %) expelled air from syringes Disposal 47 (61 %) contaminated needles in a puncture-proof container 8 (10 %) disposed through incineration Spill management 20 (26 %) wiped spill from skin with tissue paper Handling bodily fluids 32 (42 %) educated patients and visitors about handling bodily fluids Overall handling (not differentiated into activity) 43 (56 %) wore protective clothing during exposure 8 (10 %) used luer-lock syringes for preparation and administration 40 (52 %) took safety precautions during handling 56 (73 %) wore gloves 28 (36 %) wore apron 13 (17 %) wore goggles 36 (47 %) wore N95 mask 16 (21 %) wore headcover Practice Mean 22.1 (± 5.50) (0–40)
Baykal et al., 2009 (Turkey)[a]	To determine the problems of nurses who work on oncology units and administer cytotoxic drugs, with their working conditions, personal rights and working life, to compare the differences among hospitals, and to reveal their level of compliance with legislation	Cross-sectional study Self-administered questionnaire (newly developed)	N = 171 oncology nurses; inpatient: from n = 25 private, n = 59 university and n = 87 public hospitals. Population of nurses working in oncology units in hospitals within Istanbul province, 180 questionnaires distributed and 171 returned	Policies and guidelines 55 (32 %) complied with procedures Administration procedures exist 23 (92 %) reported by those in private hospitals 37 (64 %) reported by those in university hospitals 30 (37 %) reported by those in public hospitals Preparation procedures exist 24 (14 %) reported by those in private hospitals 44 (26 %) reported by those in university hospitals 35 (21 %) reported by those in public hospitals Education and professional development 10 (6 %) overall (n = 171) had taken a short course	Preparation 135 (79 %) prepared cytotoxic drugs 68 (40 %) used biological safety cabinet 64 (37 %) in the nurses' office 27 (16 %) in the room used for tea breaks, meals, other purposes. Legislation that drugs are prepared by nurses Nurses were responsible for preparation 6 (24 %) reported by those in private hospitals 57 (97 %) reported by those in university hospitals 72 (83 %) reported by those in public hospitals Disposal 77 (45 %) had special disposal containers 47 (28 %) used medical waste bags 25 (15 %) trained personnel collected and stored Spill management Nurses contaminated 85 (50 %) when contaminated with drug reported normal cleaning 72 (42 %) took care to wash off the drug 14 (8 %) used an emergency spill kit Environment contaminated 88 (52 %) reported normal cleaning 64 (37 %) cleaned according to the area 19 (11 %) used an emergency

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					clean-up set Handling bodily fluids Nurses did not use any special procedures Overall handling (not differentiated into activity) 162 (95 %) wore gloves 89 (52 %) wore gown 32 (19 %) wore goggles 154 (90 %) wore mask 168 (98 %) washed their hands before smoking or drinking tea 97 (57 %) worked when pregnant or breastfeeding 48 (28 %) were not given permission to change ward when pregnant 26 (15 %) continued to work in the same manner as before when pregnant Gloves and mask 24 (96 %) reported by those in private hospitals 57 (97 %) reported by those in university hospitals 81 (93 %) reported by those in in public hospitals
Ben-Ami et al., 2001 (Israel)[a]	To examine the influence of the nurses' beliefs, attitudes, and knowledge concerning occupational exposure, on their behaviour and proper use of recommended protective measures. To understand the factors that promote or hinder the nurses' behaviour while handling cytotoxic drugs in their daily work surroundings	Cross-sectional study Self-administered questionnaire (adapted, source not stated) and direct observation	N = 61 nurses; n = 31 oncology inpatient and n = 30 control group community nurses Population exposed nurses from 2 hospitals in Israel The oncology nurses' data is reported here	Policies and guidelines 26 (87 %) had guidelines and procedures 11 (41 %) guidelines were regularly reviewed Education and professional development 21 (68 %) had formal information of the occupational risks of cytotoxic drugs Knowledge of the risk 29 (94 %) safety measures important for young and old nurses 24 (77 %) gloves important when mixing and administering 21 (68 %) did not agree cytotoxic drugs absorbed into their blood stream Perceived susceptibility to exposure Drawing from vial Mean 5.35 (± 1.42) (1–7) Mixing Mean 5.71 (± 1.44) (1–7) Administering Mean 4.67 (± 1.92) (1–7) Connecting intravenous lines Mean 4.29 (± 2.12) (1–7) Needle sticks Mean 6.06 (± 1.44) (1–7) Direct skin contact Mean 5.81 (± 1.45) (1–7) Inhaling Mean 6.06 (± 1.26) (1–7) Eating/drinking near Mean 4.51 (± 2.17) (1–7) Eye splash Mean 6.32 (± 0.98) (1–7) Attitude or factor affecting knowledge and practice Self-efficacy 7 (23 %) highly capable	Preparation Questionnaire 20 (65 %) washed hands before and/or after 18 (58 %) wore surgical gloves 17 (55 %) used laminar airflow 2 (6 %) wore mask 7 (23 %) wore gown 8 (26 %) wore working suit only 29 (94 %) other nurses drink and smoke in the preparation area; 12 (39 %) reported nurse did occasionally themselves Observation n = 8 7 (88 %) used laminar air flow hoods Administration Questionnaire 15 (48 %) washed hands before and/or after 10 (32 %) wore surgical gloves 1 (3 %) wore a mask 1 (3 %) wore a gown 7 (23 %) wore a working suit only 3 (10 %) used no protective measures Observation n = 14 6 (43 %) used pads to absorb liquids from vials and intravenous lines Overall handling (not differentiated into activity) Observation n = 22 Preparation and administration 21 (98 %) wore latex gloves 22 (100 %) used aseptic technique

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Reasons for behaviour 14 (44 %) did not feel comfortable 7 (22 %) forgot to use protective measure because of work pressures 7 (22 %) there was not a need for protective measures 17 (55 %) gloves did not interfere with sensation 23 (74 %) personal protective equipment did not create a psychological barrier between them and their patients	
Banihani et al., 2022 (France)	To obtain a comprehensive picture of the perceptions, knowledge, and handling practices of all healthcare workers in oncology day hospitalisation units and compounding units regarding the risk of exposure to antineoplastic drugs.	Descriptive study Interview-administered two questionnaires – one for care units and one for compounding units (perception questions adapted from Hon et al., 2015)	N = 64 participants from two day oncology cancer centres; n = 27 nurses, n = 23 pharmacy professionals, n = 7 physicians, n = 7 auxiliary caregivers. Whole population participated. The nurses' data is reported here	Knowledge of the risk Education/knowledge Median 28 % Attitude or factor affecting knowledge and practice Perception Median 57 %	Overall handling (not differentiated into activity) Handling practice score Median 50 %
Boiano et al., 2014 (United States)[a]	To describe chemotherapy drug administration practices and extent of use of exposure controls, and impediments to personal protective equipment use by health care workers who administer antineoplastic drugs	Cross-sectional study Self-administered questionnaire online 'NIOSH health and safety practices survey of healthcare workers - administration of antineoplastic drugs module' (newly developed)	N = 2069 oncology nurses; administered antineoplastics in the last week, 'n' varied for individual items Population members of professional practice organisations	Policies and guidelines 1936 (94 %) employer has procedures for safe administration 1507 (73 %) very familiar with Oncology Nursing Society (ONS) guidelines 271 (47 %) with Occupational Safety and Health Administration (OSHA) guidelines 515 (25 %) with National Institute for Occupational Safety and Health (NIOSH) guidelines 247 (12 %) with American Society of Health-System Pharmacists (ASHP) guidelines Education and professional development 1958 (95 %) had training 702 (36 %) training had been more than 12 months ago 1460 (75 %) completed Oncology Nursing Society (ONS) courses Attitude or factor affecting knowledge and practice FOR ADMINISTRATION (top 3 responses): Not wearing gloves (n = 218) 78 (36 %) skin exposure was minimal 68 (31 %) not provided by employer 63 (29 %) not part of protocol Not wearing a gown (n = 820) 344 (42 %) skin exposure was minimal 76 (35 %) not part of protocol 172 (21 %) no one else who does this work uses them Not wearing eye protection (n = 1654) 777 (47 %) not part of our protocol 728 (44 %) exposure was minimal 364 (22 %) an engineering	Preparation 611 (32 %) primed intravenous tubing 115 (6 %) primed intravenous tubing with antineoplastic drug 668 (35 %) primed intravenous tubing with a non-drug fluid such as saline Intravenous priming from pharmacy 229 (12 %) with antineoplastic drug 1184 (62 %) with a non-drug fluid such as saline 401 (21 %) not primed 64 (13 %) crushed tablets/ opened capsules n = 57 of those that crushed tablets/opened capsules (could select more than one response) 19 (33 %) at bedside 19 (33 %) clinical areas 19 (33 %) pharmacy 8 (7 %) other **Administration** 853 (45 %) used Closed System drug-Transfer Device (CSTD) 1733 (90 %) used needleless systems 1812 (94 %) used luer-lock fittings 1135 (59 %) used absorbent pad under injection site 1468 (73 %) stored preparation in a restricted area 1840 (92 %) washed hands after removing gloves 1838 (98 %) replaced damaged or contaminated gloves 1676 (85 %) wore gloves 352 (20 %) wore double gloves 1147 (58 %) wore gown 226 (12 %) wore eye or face

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				control was being used Not wearing a mask (n = 1881) 1241 (66 %) not part of our protocol 621 (33 %) exposure was minimal 339 (18 %) an engineering control was being used	protection 39 (2 %) wore respirator or N95 mask 78 (4 %) wore head cover 60 (3 %) wore shoe covers n unknown (20 %) wore surgical mask 20 (1 %) reused gloves While wearing gloves used for administration 1201 (61 %) touched intravenous pump or bed controls 532 (27 %) touched waste basket 512 (26 %) used pens/pencils 394 (20 %) touched doorknobs, cabinets, or drawers 256 (13 %) used computer or calculator 217 (11 %) handled files or charts Spill management 84 (4 %) had direct skin contact 27 (1 %) skin was punctured by a sharp in the past 12 months 230 (12 %) had administration spill/leak in the past week 166 (71 %) spill while attaching, injecting, or detaching intravenous line 77 (33 %) spill due to bad connection 51 (22 %) spill due to equipment malfunction 44 (19 %) spill while drawing up or expelling air from syringe 40 (17 %) spill due to excessive pressure in vial 181 (78 %) spill volume less than 5 mL 21 (9 %) spill volume 5 mL or more 17 (9 %) spill not always cleaned up 58 (3 %) spill kits were not available/did not know if they were Overall handling (not differentiated into activity) 237 (12 %) took home clothing that had contact with chemotherapy
Boiano et al., 2015 (United States)	To describe work practices including use of exposure controls and barriers to using personal protective equipment by nurses, pharmacists and pharmacy technicians who compound and handle antineoplastic drugs	Cross-sectional study Self-administered questionnaire online 'NIOSH health and safety practices survey of healthcare workers - compounding of antineoplastic drugs module' (newly developed)	N = 424 healthcare workers; n = 241 oncology nurses, n = 183 pharmacy practitioners; compounded antineoplastic drugs in the 7 days prior, n = 201 (84 %) outpatient, n = 38 (16 %) inpatient, n = 1 (<1 %) nursing and residential care, 'n' varied for individual items Population members of professional practice organisations	Policies and guidelines 192 (80 %) employer had procedures addressing safe compounding 182 (76 %) very familiar with Oncology Nursing Society (ONS) guidelines 125 (52 %) with Occupational Safety and Health Administration (OSHA) guidelines 71 (30 %) with National Institute for Occupational Safety and Health (NIOSH) guidelines	Preparation 196 (92 %) wore gloves 31 (15 %) wore double gloves 136 (62 %) wore gown 23 (11 %) wore eye or face protection 15 (7 %) wore respirator or N95 mask 203 (89 %) used biological safety cabinet 208 (91 %) dedicated room Transferring liquid antineoplastic drugs 56 (25 %) used Closed System drug-Transfer Device (CSTD)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
			The oncology nurses' data is reported here	43 (18 %) with American Society of Health-System Pharmacists (ASHP) guidelines Education and professional development 217 (91 %) had training 105 (48 %) had received training more than 12 months ago Attitude or factor affecting knowledge and practice FOR PREPARATION (top 3 responses): Not wearing gloves (n = 17) 6 (35 %) skin exposure was minimal 5 (29 %) not part of protocol 4 (24 %) not readily available in work area Not wearing a gown (n = 81) 29 (36 %) not part of protocol 25 (31 %) skin exposure was minimal 22 (27 %) an engineering control was being used Not wearing eye protection (n = 184) 77 (42 %) an engineering control was being used 72 (39 %) not part of our protocol 48 (26 %) exposure was minimal Not wearing a mask (n = 194) 87 (45 %) not part of our protocol 81 (42 %) an engineering control was being used 43 (22 %) exposure was minimal	92 (41 %) used needleless system 22 (10 %) used glove box 101 (45 %) used none of the above 72 (34 %) primed intravenous tubing inside a ventilated cabinet or isolator 172 (81 %) primed intravenous tubing with a non-drug fluid such as saline 6 (20 %) crushed tablets and/or opened capsules during the past week Spill management 24 (11 %) skin came in direct contact 13 (6 %) accidentally punctured their skin by a sharp in the past 12 months 9 (8 %) spill not always cleaned up inside cabinet 5 (11 %) spill not always cleaned-up outside of a ventilated cabinet or isolator 9 (4 %) spill kits were not available or nurses did not know if they were Overall handling (not differentiated into activity) 9 (4 %) reused gloves 36 (16 %) did not always wash their hands after removing gloves 7 (3 %) did not always change gloves when they became damaged or contaminated 81 (48 %) did not always replace gowns after use for more than 3 h Administration Missing from local guidelines N = 211 intravenous administration events 161 (76 %) wore double gloves 49 (23 %) wore single gloves 1 (1 %) no gloves were worn 0 (0 %) wore gown
Brink, 2016 (China) Dissertation	To observe and describe the compliance to National Institute for Occupational Safety and Health (NIOSH) guidelines and recommendations in terms of personal protective equipment use in clinical practice by registered nurses administering antineoplastic drugs at a public hospital in Guangzhou, China	Cross-sectional study Direct observations using template (adapted from National Institute for Occupational Safety and Health (NIOSH), 2014	N = 27 oncology nurses; n = 211 instances of intravenous administration of antineoplastic drugs		
Callahan et al., 2016 (United States)	To identify factors associated with oncology nurses' use of hazardous drug safe-handling precautions in inpatient clinical research units	Cross-sectional study Self-administered online 'Hazardous drug handling' questionnaire (Polovich and Clark, 2012), questions and results reported	N = 115 oncology nurses; 4 oncology and 1 ICU inpatient units. Population of 196 clinical research nurses, response rate 59 %	Education and professional development 110 (96 %) completed Oncology Nursing Society (ONS) chemotherapy and biotherapy training course 46 (40 %) certified in oncology nursing Knowledge of the risk Mean 10.16 (± 1.46) (0–12) Attitude or factor affecting knowledge and practice Self-efficacy for using personal protective equipment (n = 105) Mean 23.69 (± 3.43) (7–28) Perceived barriers (n = 105) Mean 21.12 (± 5.74) (15–52) Perceived risk (n = 105) Mean 20.68 (± 3.2) (7–28) Interpersonal influence (n = 104)	Preparation n = 13 (11 %) Possible score (0 never-5 always) Used biological safety cabinet Mean 0.85 (± 1.72) Used Closed System drug-Transfer Device (CSTD) Mean 3.69 (± 2.14) Wore double gloves Mean 3.46 (± 1.9) Wore hazardous drug-designated gloves Mean 3.92 (± 1.93) Wore hazardous drug-designated gown Mean 4.15 (± 1.86) Wore Eye protection Mean 2.46 (± 2.22) Wore Respirator Mean 3.31 (± 2.18)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Mean 10.97 (± 2.21) (0–12) Conflict of interest (n = 103) Mean 6.65 (± 2.14) (4–16) Workplace safety climate (n = 101) Mean 69.89 (± 9.3) (21–84)	Administration n = 110 (96 %) Possible score (0 never-5 always) Used Closed System drug-Transfer Device (CSTD) Mean 4.69 (± 0.99) Wore Double gloves Mean 3.67 (± 1.77) Wore hazardous drug-designated gloves Mean 4.83 (± 0.72) Wore hazardous drug-designated gown Mean 4.64 (± 1.06) Wore Eye protection Mean 2.4 (± 2.16) Wore respirator Mean 2.18 (± 2.04) Disposal n = 100 (91 %) Possible score (0 never-5 always) Wore double gloves Mean 3.2 (± 2.09) Wore hazardous drug-designated gloves Mean 4.81 (± 0.74) Wore hazardous drug-designated gown Mean 4.55 (± 1.12) Wore Eye protection Mean 2.46 (± 2.2) Wore Respirator Mean 2.18 (± 2.21) Spill management 10 (9 %) reported exposure event in last 12 months Handling bodily fluids n = 101 (88 %) Possible score (0 never-5 always) Wore double gloves Mean 2.34 (± 2.14) Wore hazardous drug-designated gloves Mean 3.76 (± 1.56) Wore hazardous drug-designated gowns Mean 2.64 (± 2.05) Wore Eye protection Mean 1.54 (± 2) Wore Respirator Mean 1.48 (± 1.92) Overall handling (not differentiated into activity) 54/102 (53 %) nurses incorrectly thought surgical masks provided aerosol protection
Chaudhary and Karn, 2012 (Nepal)	To evaluate the knowledge of nurses' regarding exposure of cytotoxic drugs and to determine the current patterns of use of personal protective equipment while handling antineoplastic chemotherapeutic agents	Cross-sectional study Two self-administered questionnaires (newly developed) and direct observation	N = 125 nurses work with cytotoxic drugs; n = 55 internal medicine, n = 33 surgery, n = 14 paediatric, n = 13 gynaecology and n = 10 ENT (ear, nose and throat) nurses. Response rate reported 87 %	Education and professional development 0 (0 %) training program Source of information about cytotoxic drugs 108 (86 %) textbooks and the internet 6 (5 %) the hospital's administration 4 (3 %) nursing association 2 (2 %) mass media Knowledge of the risk Overall	Preparation 0 (0 %) used biological safety cabinet 21 (17 %) in treatment room 104 (83 %) at nurses' station Overall handling (not differentiated into activity) Observation preparation and risky activities 115 (92 %) wore gloves 6 (5 %) wore surgical mask 78 (62 %) wore both gloves and mask

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Mean 61.32 (± 17.12) (0–100) 36 (29 %) score above Mean Knowledge about antineoplastic agent Mean 26 (± 13.0) (range unknown) Prevention Mean 35 (± 9.0) (range unknown) Exposure Mean 33 (± 26.0) (range unknown) Attitude or factor affecting knowledge and practice Perceived risky activities 42 (34 %) change bed sheets 32 (25 %) change nasogastric tube 27 (22 %) change urinary catheter 14 (11 %) handle excreta 121 (97 %) change intravenous line and/or cannula	
Colvin et al., 2016 (United States)	The aims of the pilot study were to examine actual and subjective ambulatory oncology nurse adherence to chemotherapy safe-handling guideline recommendations that prevent chemotherapy exposure.	Cross-sectional study Self-administered questionnaire (newly developed) and checklist (newly developed)	N = 12 oncology nurses; outpatient. Population of 33 nurses, response rate 36 %. 22 direct observations events (checklist used)	Education and professional development 2 (17 %) oncology certified	Preparation Chemotherapy medications received from pharmacy Checklist 1 (8 %) (n = 13 observations) absorbent pad as work surface 4 (21 %) (n = 19 observations) single gloves to remove chemotherapy agents from transport bag 8 (42 %) (n = 19 observations) double gloves to remove chemotherapy agents from transport bag Administration Questionnaire 9 (75 %) wore double gloves 7 (58 %) removed outer gloves prior to programming intravenous pump 11 (92 %) washed hands after glove removal 2 (17 %) wore double gloves during disconnect 7 (58 %) wrapped gauze pad around connection site 12 (100 %) used chemotherapy gown during administration 9 (75 %) removed gown prior to leaving room at disconnection 12 (100 %) disposed of equipment in correct container Checklist 18 (90 %) gown with first pair of gloves under ribbed cuff 15 (75 %) (n = 20 observations) second pair of gloves over ribbed cuff 7 (44 %) (n = 16 observations) outer gloves removed prior to programming intravenous pump 17 (89 %) (n = 19 observations) gown removed

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					prior to leaving room 9 (75 %) (n = 12 observations) washed hands Disconnecting 0 (0 %) (n = 2 observations) removed gown prior to leaving room 1 (17 %) (n = 6) observations double gloves and gown worn 1 (17 %) (n = 6 observations) gauze wrapped around connection site and chemotherapy bag left attached 6 (100 %) (n = 6 observations) washed hands Disposal Checklist 20 (100 %) (n = 20 observations) gloves into chemotherapy waste container after starting intravenous 6 (100 %) (n = 6 observations) chemotherapy bag discarded with attached secondary tubing into chemotherapy waste container 5 (83 %) (n = 6 observations) gloves disposed into chemotherapy waste container after disconnecting Administration 1705 (94 %) used luer-lock fittings 1651 (91 %) used needleless systems 816 (45 %) used Closed System drug-Transfer Device (CSTD) 1578 (87 %) wore gloves 363 (20 %) wore double gloves 1070 (59 %) wore a non-absorbent gown 200 (11 %) wore eye or face protection Spill management 1778 (98 %) spill kits were available 256 (14 %) experienced either a spill/leak and/or skin contact while administering during the previous week 417 (23 %) medical surveillance in workplace 163 (9 %) exposure monitoring in workplace
DeJoy et al., 2017 (United States)[a]	The aim of this study was to examine predictors of the use of personal protective equipment and engineering controls and adverse events involving liquid antineoplastic drugs in a relatively large and diverse sample of nurses. Particular interest was with examining the role of safety-related organisational practices and perceived safety climate	Cross-sectional study Self-administered online 'NIOSH health and safety practices survey of healthcare workers - Antineoplastic drug administration module' (newly developed)	N = 1814 oncology nurses; inpatient and outpatient, administered liquid antineoplastic drugs within last 7 days. Population members of professional practice organisations	Policies and guidelines 1723 (95 %) employer had specific procedures documented 1451 (81 %) very familiar with at least one of American Society of Health-System Pharmacists (ASHP), Oncology Nursing Society (ONS), National Institute for Occupational Safety and Health (NIOSH) or Occupational Safety and Health Administration (OSHA) guidance documents Education and professional development 1741 (96 %) had received training 599 (33 %) no training within the previous 12 months Attitude or factor affecting knowledge and practice Safety climate factors measured: management commitment, risk perception, safety voice or reporting. Questions and results reported in data, part of multiple logistic and Poisson regressions	
Friese et al., 2020 (United States)	To describe nurses' hazardous drug exposures and use of personal protective equipment during drug spills	Retrospective cohort study Self-administered online 'Drug exposure feedback and education for nurses' safety (DEFENS)' questionnaire (adapted from Polovich and Clark, 2012; Vogus and Sutcliffe, 2007; Friese, 2012)	N = 393 oncology nurses; outpatient 61 spill reports from n = 51 nurses. Population from 12 cancer centres over two years	Education and professional development 186 (49 %) Oncology Certified Nurse 144 (38 %) Oncology Nursing Society (ONS) /Oncology Nursing Certification Corporation (ONCC) Chemotherapy Immunotherapy	Spill management Volume spilled Mean 28.8 mL (± 42.3) (Range 'a few drops' to 250 mL) Spill reports (n = 61) 41 (71 %) Closed System drug-Transfer Device (CSTD) used; 21 (51 %) did not work properly

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				22 (6 %) other training 92 (24 %) no training	11 (18 %) skin exposure 26 (43 %) double gloves worn 33 (54 %) single gloves worn 2 (3 %) no gloves worn 38 (62 %) single use disposable gown worn 14 (23 %) eye protection worn 18 (30 %) respirator worn 7 (11 %) shoe covers worn 42 (69 %) spill kit used 6 (10 %) alcohol-based hand gel used after clean-up
Fuller et al., 2007 (United States)[a]	To identify the extent to which nurses are exposed to hazardous drugs in the workplace and to begin determining the extent that concerns identified in the NIOSH Alert (National Institute for Occupational Safety and Health) have been addressed	Cross-sectional study 'Self-administered 'Hazardous drug information form' questionnaire (newly developed)	N = 400 nurses; members of Massachusetts Nurses Association (MNA). 2000 questionnaires were distributed to Massachusetts Nurses Association nurses at 3 hospitals, response rate 20 %	Education and professional development 48 (12 %) had classroom training 24 (6 %) hands-on training	Preparation 344 (86 %) crushed or prepared drugs 328 (82 %) crushed solid drugs 320 (80 %) prepared liquid drugs Engineering controls 176 (44 %) had any controls 164 (41 %) had no controls 16 (4 %) had closed and exhausted mixing systems Spill management 128 (32 %) no spill kits available Handling bodily fluids 76 (19 %) contamination controls used 64 (16 %) special handling of linen Overall handling (not differentiated into activity) 348 (87 %) handled or administered hazardous drugs 280 (70 %) used personal protective equipment 272 (68 %) wore gloves 32 (8 %) wore splash proof apron 148 (37 %) wore gown 8 (2 %) wore lab coat 72 (18 %) wore goggles 100 (25 %) wore safety glasses 60 (15 %) wore face shield 64 (16 %) wore surgical mask 68 (17 %) wore N95 mask
Goodman, 1985 (UK)[a]	To describe current practice, see which cytotoxic drugs were used in which clinical areas, examine the precautions taken in mixing, giving and disposing of cytotoxics, discover who had received training and if they had concerns related to use.	Cross-sectional study Self-administered questionnaire (newly developed)	N = 32 hospital staff; n = 20 nurses, n = 11 medical staff, n = 1 theatre technician. Population from 18 clinical areas within 3 hospitals. The nurses' data is reported here	Education and professional development 2 (10 %) had training specifically for cytotoxic drugs Knowledge of the risk 11 (55 %) had no concerns	Preparation 1 (5 %) used a separate room 2 (10 %) in the patients' room Disposal 3 (15 %) used separate waste container and copious amounts of water when flushing down the sink Spill management 3 (15 %) would wear protective clothes 1 (5 %) would contact pharmacy for advice 1 (5 %) close to water when handling Overall handling (not differentiated into activity) 18 clinical areas cytotoxic drugs were handled only by trained staff; 10 areas where nurses handled, 4 only ward sisters

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					10 (50 %) washed hands 7 (35 %) wore polyvinyl chloride (PVC) gloves 3 (15 %) wore non-polyvinyl chloride (PVC) gloves 1 (5 %) wore no gloves 4 (20 %) wore plastic apron 9 (45 %) wore goggles 2 (10 %) wore mask 9 (45 %) no contact with cytotoxic drugs, although used in ward
Graeve et al., 2017 (United States)	To determine key factors influencing exposure to antineoplastic agents for nursing and pharmacy staff working in oncology and whether their work surfaces were contaminated with these agents	Cross-sectional study Self-administered online 'Hazardous drug handling' questionnaire (adapted from Polovich and Clark, 2012), surface contamination kit, questions and results reported	N = 89 oncology nurses; n = 27 inpatient, n = 45 bone marrow transplant units, n = 17 out-patient chemotherapy, n varied for individual items	Education and professional development 36 (41 %) oncology certified Knowledge of the risk Data not reported for knowledge Attitude or factor affecting knowledge and practice Data not reported for perceived barriers, perceived risk, self-efficacy, safety climate, interpersonal influence and conflict of interest	Preparation Preparation by pharmacy Administration 51 (60 %) used Closed System drug-Transfer Device (CSTD) 68 (83 %) wore chemotherapy gloves 8 (11 %) wore other gloves 26 (34 %) wore double gloves 67 (82 %) wore chemotherapy gown 2 (3 %) wore other gown 2 (3 %) reused disposable gowns 22 (28 %) wore eye protection 9 (12 %) wore respirator Disposal 75 (80 %) wore chemotherapy gloves 8 (11 %) wore other gloves 26 (33 %) wore double gloves 45 (56 %) wore chemotherapy gown 2 (3 %) wore other gown 3 (4 %) reused disposable gowns 17 (22 %) wore eye protection 7 (9 %) wore respirator Handling bodily fluids 64 (70 %) wore chemotherapy gloves 13 (18 %) wore other gloves 7 (9 %) wore double gloves 16 (21 %) wore chemotherapy gown 7 (9 %) wore other gown 0 (0 %) reused disposable gowns 11 (15 %) wore eye protection 4 (5 %) wore respirator Overall handling (not differentiated into activity) 28 % were pregnant while working, 4 % sought alternative duties 72 % not pregnant while working; 33 % would seek alternative duties if they became pregnant, 26 % unsure if they would
He et al., 2017 (United States)	To identify associations between organisational factors and reported barriers and two key outcomes, Personal Protective Equipment used and self-reported drug spills	Cross sectional study Self-administered 'Revised hazardous drug handling questionnaire (Polovich and Clark, 2012), Reported hazardous drug spills, Safety organising scale (Vogus and Sutcliffe,	N = 437 oncology nurses; outpatient, members of the Oncology Nursing Society (ONS), n = 252 routinely prepare or administer hazardous drugs. Population of 654	Attitude or factors affecting knowledge and practice Reported hazardous drug spill Yes n = 51, No n = 199 (n = 23 excluded) Safety organising scale spill report Mean 5.2 (± 1) (1–7)	Administration Route of exposure (n = 252) 9 (18 %) prepping/spiking intravenous bags 25 (49 %) starting/during infusion Spill management 51 (20 %) spill, drop or leak

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
		2007), Practice environment scale of the nursing work index (PES_NWI) (Shang et al., 2013), Geer's dermal exposure survey (Geer et al., 2006)'	Oncology Nursing Society nurses, response rate 67 %	spill not reported Mean 5.6 (± 1) (1–7) Practice environment scale of the nursing work index (PES-NWI) Nurse participation: spill report Mean 2.8 (± 0.9) (1–5) spill not reported Mean 3.1 (± 0.9) (1–5) Leadership/support: spill report Mean 3.3 (± 1) (1–5) spill not reported Mean 3.6 (± 0.9) (1–5) Collegiality: spill report Mean 3.8 (± 0.9) (1–5) spill not reported Mean 4 (± 0.8) (1–5) Staffing/resources: spill report Mean 3.3 (± 1) (1–5) spill not reported Mean 3.4 (± 1) (1–5) Nursing quality of care: spill report Mean 4.1 (± 0.4) (1–5) spill not reported Mean 4.3 (± 0.6) (1–5) Supportive medical assistant relations: spill report Mean 3.6 (± 1) (1–5) spill not reported Mean 3.9 (± 0.87) (1–5) Geer's dermal exposure survey (Mean 13 items) spill reported Mean 3 (± 0.5) (1–5) spill not reported Mean 3.3 (± 0.5) (1–5)	of 5 mL or more within the last 6 months n = 51 5 (10 %) skin or eye contact 25 (49 %) somewhat or strongly concerned Spill clean-up 41 (80 %) wore a gown 29 (57 %) used chemotherapy gloves 20 (39 %) wore double gloves 28 (55 %) wore respirators/ masks 23 (45 %) wore eye protection Overall handling (not differentiated into activity) 224 (90 %) wore one pair of gloves at least 75 % time Route of exposure (n = 252) 8 (16 %) patient related activities 8 (16 %) storing/disposing of drugs 2 (4 %) due to equipment malfunction 10 (59 %) (n = 17) Closed System drug-Transfer device (CSTD) malfunction Personal protective equipment use score Mean 2.4 (± 1) (0–5)
Hon et al., 2015 (Canada)[a]	To survey a broad range of potentially exposed health care workers from British Columbia, Canada with respect to their knowledge and perceptions regarding antineoplastic drugs as well as their behaviour associated with safe work practices	Cross-sectional study Self-administered questionnaire (developed/ adapted from findings and studies Connor et al., 2010, Nichol et al., 2008, Geer et al., 2006), questions available and results reported	N = 120 contact with antineoplastics; n = 33 nurses, n = 21 pharmacists, n = 31 other pharmacy staff, n = 11 transport, n = 12 unit clerk, n = 12 others; inpatient facilities Response rate unable to be calculated due to recruitment method The nurses' data is reported here	Education and professional development 23 (70 %) trained on workplace health and safety of antineoplastic drugs Knowledge of the risk 33 (100 %) skin is a possible route of exposure 31 (94 %) work surfaces may be contaminated 29 (88 %) site had a dedicated preparation area 33 (100 %) separate disposal method 33 (100 %) site had a safe drug handling policy Attitude or factor affecting knowledge and practice 12 (36 %) risk of exposure is low 5 (15 %) afraid of working with or near antineoplastic drugs 23 (69 %) safety measures currently in place are suitable 24 (73 %) workers around me are handling antineoplastic drugs safely 24 (73 %) handle all situations where there is potential exposure 31 (94 %) personal protective	Overall handling (not differentiated into activity) 32 (97 %) handled, prepared and/or administered antineoplastic drugs 25 (76 %) wore gloves 13 (40 %) wore gloves in an area where antineoplastic drugs had been handled 8 (24 %) washed hands after glove use 12 (36 %) washed hands after being in an area where antineoplastic drugs had been handled

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				equipment is readily available 31 (94 %) I am able to use the required personal protective equipment properly	
Jeong et al., 2015 (South Korea)	To identify the general management characteristics and the current anticancer drug management and analyse the relationship between such variables in terms of recognition and the performance level of the safety regulations for anticancer drugs	Cross-sectional study Self-administered questionnaire (adapted from Choi et al., 2004)	N = 236 chemotherapy; inpatient and outpatient. Population from five hospitals in and near Seoul, size unknown	Education and professional development 144 (61 %) safety education at nursing school 165 (70 %) safety education at work 167 (71 %) want more education Knowledge of the risk Awareness of safety rules Mean 3.4 (± 0.55) (1–4) Route of exposure 92 (22 %) when intravenous line change 88 (21 %) when drug is removed 76 (18 %) when drug is connected 73 (17 %) when intravenous set is connected to bottle of drug 39 (9 %) when drug is spilled and cleaned up 31 (7 %) when drug is mixed 15 (4 %) inhalation 12 (3 %) when dealing with waste products	Preparation 21 % in pharmacy 3 % in medical units 76 % both pharmacy and medical unit 9 % eat food where drugs are prepared Spill management 144 (61 %) had an exposure experience Overall handling (not differentiated into activity) Performance of safety rules Mean 2.38 (± 0.98) (1–4)
Karadakovan, 1999 (Turkey)	To investigate the protective nursing precautions taken during preparation and administration of chemotherapy by the nursing staff	Cross-sectional study Interviewer-administered questionnaire (newly developed)	N = 55 chemotherapy nurses. Population of 60 nurses, response rate 92 %	Education and professional development 13 (24 %) in-service education Knowledge of the risk 52 (95 %) aware of protective precautions for administration 50 (91 %) prepare chemotherapy in biological safety cabinet 50 (91 %) gloves preparation 48 (87 %) apron preparation 50 (91 %) mask preparation 49 (89 %) wash hands before and after preparation 30 (55 %) air into ampoule before removing drug 39 (71 %) air out ampoule before removing needle 49 (89 %) double gloves when pouring 44 (80 %) eye glasses and mask when pouring 51 (93 %) gloves administration 50 (90 %) apron administration 50 (90 %) mask administration 38 (69 %) gauze over intravenous ports for air removal 51 (93 %) wash hands after administration Attitude or factor affecting knowledge and practice Hospital management should: 42 (29 %) have a separate preparation room 37 (26 %) have enough supplies of personal protective equipment 11 (8 %) provide in-service education 10 (7 %) limit time nurse working with chemotherapy	Preparation 13 (24 %) used biological safety cabinet 46 (84 %) wore gloves 17 (31 %) wore apron 23 (42 %) wore mask 47 (85 %) washed hands before and after 28 (51 %) air into ampoule before removing drug 32 (48 %) air out ampoule before removing needle 21 (38 %) wore double gloves when pouring 11 (20 %) wore eye glasses and mask when pouring Administration 37 (67 %) wore gloves 14 (25 %) wore apron 22 (40 %) wore mask 20 (36 %) used gauze over intravenous ports for air removal 43 (78 %) washed hands after Overall handling (not differentiated into activity) 20 (36 %) administered chemotherapy during pregnancy

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				6 (4 %) rotational work 4 (3 %) periodic health controls 3 (2 %) launder work clothes in hospital	
Kim et al., 2019 (South Korea)	To examine the safe handling practice of chemotherapeutic agents by Korean nurses working in inpatient units and to examine the relationship between Korean nurses' perceptions of the hospital safety climate and adherence to the safety guidelines for handling chemotherapeutic agents	Prospective cohort study Self- administered electronic questionnaire 'The Korea Nurses' health study (KNHS)' (adapted from Gershon et al., 2000 and Nurses' health study 3 (NHS3) revised Gaskins et al., 2015)	N = 872 chemotherapy nurses, inpatient, administered chemotherapy in last 30 days. From a population of 6731 nurses that completed the larger KNHS, overall population not known	Attitude or factor affecting knowledge and practice Hospital safety climate Equipment availability Mean 4.46 (± 0.78) (1–5) Management support Mean 3.60 (±0.93) (1–5) Absence of job hindrances Mean 2.71 (± 0.88) (1–5) Feedback/training Mean 3.44 (± 0.78) (1–5) Cleanliness/orderliness Mean 3.40 (± 0.77) (1–5) Minimal conflict/good communication Mean 3.32 (± 0.78) (1–5)	Disposal 730 (84 %) safely managed medical waste Spill management 767 (88 %) prepared spill kits in the event of exposure to chemotherapeutic agents Overall handling (not differentiated into activity) Safety adherence 447 (51 %) used the designated space 466 (53 %) performed preparation safely and used appropriate tools for administration 116 (13 %) wore protective clothing 683 (78 %) wore protective hand gear 58 (7 %) wore protective eye gear 390 (45 %) wore protective respiratory gear
Kosgeroglu et al., 2006 (Turkey)	To determine the levels of information healthcare workers possess concerning protection of themselves and the environment from the toxic effects of the drugs, as well as to observe deficits in the safe handling of chemotherapeutic drug preparation and administration	Cross-sectional study Interviewer-administered questionnaire (newly developed) and observation form (newly developed)	N = 121 chemotherapy nurses; inpatient. Population from 3 healthcare workplaces, 158 nurses approached, response rate 77 %	Education and professional development 9 (7 %) had attended periodic in-services	Preparation Questionnaire 80 (66 %) washed hands before 20 (17 %) used biological safety cabinet 11 (9 %) used absorbent cloth 3 (3 %) used special room 100 (84 %) not splashed drug during evacuation of air 49 (42 %) wiped outside liquid bottle with alcohol if contaminated 55 (46 %) wiped drug preparation area with alcohol 77 (68 %) opened ampoule with top wrapped Observation 108 (89 %) washed hands before 16 (14 %) used biological safety cabinet 9 (9 %) used absorbent cloth 2 (2 %) used special room 90 (81 %) not splashed drug during evacuation of air 17 (21 %) wiped outside liquid bottle with alcohol if contaminated 40 (44 %) wiped drug preparation area with alcohol 52 (46 %) opened ampoule with top wrapped Administration Questionnaire 115 (95 %) checked for leaks during administration 86 (71 %) wore gloves Observation 100 (89 %) checked for leaks during administration 68 (61 %) wore gloves Disposal Questionnaire 86 (75 %) disposed of gloves

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					in special garbage box 74 (61 %) placed used equipment into separate garbage 22 (34 %) used apron sent for cleaning in special laundry bag 50 (41 %) used special container for contaminated garbage 76 (63 %) used gloves with waste Observation 53 (58 %) disposed of gloves in special garbage box 18 (55 %) placed used equipment into separate garbage 14 (13 %) used apron sent for cleaning in special laundry bag 34 (32 %) used special container for contaminated garbage 60 (56 %) used gloves with waste Spill management Questionnaire 85 (70 %) would take measures if accidental contact with body Observation 64 (67 %) took measures for accidental contact with body Overall handling (not differentiated into activity) Questionnaire 108 (89 %) washed hands before drug handling 88 (77 %) washed hands after taking off gloves 109 (90 %) washed hands after completion of task 63 (54 %) used latex unpowdered glove 62 (51 %) used special glasses 11 (9 %) used mask 22 (20 %) used apron closed frontally Observation 80 (66 %) washed hands before drug handling 73 (79 %) washed hands after taking off gloves 45 (85 %) washed hands after completion of task 41 (37 %) used latex unpowdered glove 52 (48 %) used special glasses 5 (5 %) used mask 5 (6 %) used apron closed at the front
Krstev et al., 2003 (Serbia)	To establish work practices and preventative measures for nurses handling antineoplastic drugs and to determine the risk of developing symptoms	Cross-sectional study Self-administered (symptoms) questionnaire (newly developed) and interviewer-administered questionnaire (newly developed)	N = 263 nurses, inpatient and outpatient, n = 186 exposed to antineoplastics (6 hospitals), n = 77 not exposed (2 hospitals). 292 nurses selected, response rate 90 % Data on work practices reported here	Policies and guidelines Only 1 large hospital had written guidelines - unable to produce these 43 (34 %) said there were written instructions for safe work Knowledge of the risk Some medication preparation rooms were used for procedures and by staff to rest,	Preparation n = 186 (exposed nurses) 71 (38 %) used biological safety cabinet 186 (100 %) no separate room 152 (82 %) wore gloves 106 (57 %) wore mask Administration n = 186 (exposed nurses) 113 (61 %) wore gloves

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				eat and smoke Attitude or factor affecting knowledge and practice Biological safety cabinets not available in all departments and not maintained so often not used No hospital had a separate preparation room Lack of gloves in the hospital and oncology departments	63 (34 %) wore mask Disposal n = 186 (exposed nurses) 14 (8 %) used special containers
Kyprianou et al., 2010 (Cyprus)	To evaluate the knowledge, attitudes and beliefs of Cypriot nurses on the hazards associated with occupational exposure to antineoplastic agents	Cross-sectional study Two self-administered questionnaires (adapted from Türk et al., 2004)	N = 88 oncology nurses; inpatient, handle antineoplastics. Population from 3 hospitals, 105 nurses asked to participate, response rate 84 % Data on work practices and knowledge reported here	Education and professional development 29 (33 %) trained in handling cytotoxic drugs 34 (39 %) used other sources of information 28 (32 %) used information from seminars 10 (11 %) used the media as information source 16 (18 %) had in-service training 16 (18 %) professional associations used for information 3 (3 %) workers' unions used for information Knowledge of the risk Mean 79.4 (± 9.82) (0–100)	Preparation 82 (93 %) used biological safety cabinet 38 (43 %) areas without proper ventilation 45 (51 %) had proper ventilation 0 (0 %) smoked in the area 5 (6 %) drank or kept food in the area 84 (95 %) wore gloves 74 (85 %) wore a gown 70 (80 %) wore mask 28 (32 %) wore goggles 1 (1 %) no personal protective equipment Handling bodily fluids Dangerous clinical activities Changing bed sheets, urine and gastric fluid bags 75 (85 %) wore gloves 38 (43 %) wore a gown 12 (14 %) wore mask 3 (3 %) wore goggles 1 (1 %) no personal protective equipment
Lawson et al., 2019 (United States and Canada)	To assess glove and gown use among nonpregnant female nurses who had administered antineoplastic drugs within the past month and among pregnant nurses who had administered such drugs during the first 20 weeks of pregnancy	Cross-sectional study Self-administered online 'Nurses' Health Study 3 (NHS3)' questionnaire (results part of a larger study)	N = 5,65 females administer antineoplastics; nonpregnant n = 3845 glove and gown analysis, n = 1492 administration analysis (extra questions added); pregnant (first 20 weeks) n = 315 Total population unknown, open recruitment		Administration Pregnant nurses (n = 315) 271 (86 %) wore gloves 164 (52 %) wore gown Nonpregnant (n = 3845) 3059 (80 %) wore gloves 1574 (41 %) wore gown **Administration analysis (extra questions added after study started)** Nonpregnant (n = 1492) Gloves 156 (89 %) infusion only (n = 175) 141 (54 %) pills crushed (n = 259) 277 (66 %) pills intact (n = 420) 565 (89 %) combination of infusion and pills (n = 638) Gowns 98 (56 %) infusion only (n = 175) 34 (13 %) pills crushed (n = 259) 63 (15 %) pills only intact (n = 420) 366 (57 %) combination infusion and pills (n = 638)
Lee et al., 2021 (South Korea)	To investigate the effect of time pressure, knowledge of safety guidelines, and workplace safety climate on the safe handling of antineoplastic drugs by clinical nurses	Cross-sectional study Self-administered questionnaire 'Knowledge about the safety guidelines on antineoplastic agents' and 'Compliance with safe handling of antineoplastic	N = 130 nurses handle antineoplastic agents; 143 questionnaires distributed (8 incomplete) response rate 97 %	Policies and guidelines Knowledge of safety guidelines Mean 14.22 (± 2.22) (0–19) Attitude or factor affecting knowledge and practice Compliance with safe handling of antineoplastics	Preparation Preparing for injecting antineoplastic agents Mean 13.72 (± 2.89) (4–20) Administration Intravenous infusion pump Mean 36.08 (± 6.85) (10–50)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
		agents' (adapted from Yun and Park, 2016 and modified by Ko, 2017), 'Work place safety climate' (adapted from Polovich and Clark, 2012 and modified by Jung and Park, 2019), 'Time pressure scale' (adapted from Putrevu & Ratchford, 1997 and modified by Teng et al., 2010)		Mean 120.81 (± 19.26) (35–175) Time pressure Mean 28.19 (± 5.11) (5–35) Workplace safety climate Mean 55.48 (± 11.81) (18–90)	Intravenous push/ intramuscular/subcutaneous administration Mean 26.35 (±3.99) (8–40) Oral administration Mean 16.78 (± 4.67) (5–25) Disposal Mean 21.48 (± 3.29) (6–30) Handling bodily fluids Mean 6.39 (± 2.52) (2–10)
Mahon et al., 1994 (United States)[a]	To elicit information about individual implementation of the Occupational Safety and Health Administration (OSHA) guidelines for handling cytotoxic drugs, as well as information about barriers to implementing these guidelines	Cross-sectional study Self-administered questionnaire (newly developed)	N = 103, n = 83 nurses who handle cytotoxic drugs; inpatient and outpatient, members oncology nursing chapter Questionnaire was sent to all 134 members, response rate 77 % Data for nurses who handle cytotoxic drugs reported here	Policies and guidelines 78 (94 %) Occupational Safety and Health Administration (OSHA) guidelines available Education and professional development 75 (90 %) had received education on Occupational Safety and Health Administration (OSHA) guidelines 54 (65 %) received annual education on Occupational Safety and Health Administration (OSHA) guidelines Education sources: 23 (28 %) Brochures 31 (37 %) Videotapes 65 (78 %) Inservice 31 (35 %) Journal articles Attitude or factors affecting knowledge and practice Barriers to wearing personal protective equipment 26 (31 %) too busy or lack of time 14 (17 %) too hot or ill-fitting 13 (16 %) effect on patient 11 (13 %) equipment unavailable 7 (8 %) not needed 5 (6 %) too expensive 2 (2 %) takes time to put on 2 (2 %) forget 1 (1 %) difficult with gloves on 1 (1 %) gloves rip easily	Preparation n = 33 (40 %) 30 (90 %) wore gloves 3 (10 %) wore a cloth gown 15 (44 %) wore cytotoxic drug gown 13 (40 %) wore a lab coat 2 (6 %) wore no gown 10 (30 %) wore goggles 0 (0 %) wore a face shield 6 (18 %) wore a surgical mask 26 (79 %) used a biological safety cabinet 65 (82 %) cytotoxic drugs arrived on the unit properly sealed and labelled Administration n = 80 (96 %) 75 (94 %) wore gloves 3 (4 %) wore a cloth gown 47 (59 %) wore a cytotoxic gown 20 (25 %) wore a lab coat 10 (12 %) wore none 16 (20 %) wore googles 3 (4 %) wore a face shield 1 (1 %) wore a surgical mask 43 (54 %) used plastic-backed absorbent mat 65 (82 %) used luer-lock syringes 37 (46 %) syringes more than 3/4 full 33 (41 %) Infusion bags not primed 16 (20 %) primed with cytotoxic drug 24 (30 %) primed with diluent Disposal n = 80 (96 %) 32 (42 %) in administrative/ patient room 34 (45 %) in soiled utility room 9 (13 %) in pharmacy/ medication room Spill management n = 73 (88 %) 76 (91 %) aware of policy for managing a spill 20 (27 %) not involved in any cytotoxic drug spill during the previous year Handling bodily fluids n = 77 (93 %) (patient care) 72 (94 %) wore gloves 10 (13 %) wore cloth gown 9 (12 %) wore cytotoxic drug gown 8 (10 %) wore a lab coat

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					50 (65 %) wore no gown 6 (8 %) wore goggles 0 (0 %) wore a face shield 0 (0 %) wore a surgical mask 31 (37 %) gave verbal discharge instructions 8 (9 %) gave written discharge instructions Overall handling (not differentiated into activity) 68 (82 %) gave verbal discharge instructions to patients and family on rationale for personal protective equipment 7 (8 %) gave written instructions on personal protective equipment
Martin and Larson, 2003 (United States)[a]	To describe the frequency of compliance with the Occupational Safety and Health Administration (OSHA) guidelines for the handling of hazardous agents; correlate reported handling practices with size of work site, geographic area, and nursing experience; identify the use of special training programs for nurses handling antineoplastic agents; determine the presence of institutional policies and procedures related to the handling of antineoplastic chemotherapy	Cross-sectional study Self-administered 'Chemotherapy handling questionnaire' (newly developed)	N = 263 oncology nurses; outpatient, n = 250 (13 excluded - demographics collected) not all respondents answered all questions. 500 questionnaires mailed out, response rate 53 %	Policies and guidelines 213 (85 %) had policies and procedures available at work sites Education and professional development 200 (80 %) certified as Oncology Certified Nurse or Advanced Oncology Certified Nurse 218 (87 %) completed chemotherapy administration and handling program 153 (61 %) completed accredited program 20 (8 %) on-the-job training Attitude or factors affecting knowledge and practice Preparation 121 (100 %) gloves available 103 (85 %) gowns or protective garments available 65 (54 %) goggles available 67 (55 %) masks available Administration 250 (100 %) gloves available 200 (80 %) gowns or protective garments available 140 (56 %) goggles available 150 (60 %) masks available Disposal 250 (100 %) gloves available 190 (76 %) gowns or protective garments available 133 (53 %) goggles available 145 (58 %) masks available Spill management 245 (98 %) spill kits were available 250 (100 %) gloves available 233 (93 %) gowns or protective garments available 198 (79 %) goggles available 208 (83 %) masks available Handling bodily fluids 238 (100 %) gloves available 179 (75 %) gowns or protective garments available 129 (54 %) goggles available 140 (59 %) masks available	Preparation 123 (49 %) nurses reported pharmacists responsible 123 (49 %) nurses responsible n = 121 (nurses responsible - 2 responses missing) 120 (99 %) wore gloves 64 (53 %) wore gown 15 (6 %) wore goggles 8 (3 %) wore mask 121 (100 %) used laminar air flow hoods; 18 (15 %) reported turning hood off 63 (52 %) tubing primed under the hood Administration 235 (94 %) wore gloves 78 (31 %) wore gown 8 (3 %) wore goggles 3 (1 %) wore mask Disposal 235 (94 %) wore gloves 65 (26 %) wore gown 5 (2 %) wore goggles 3 (1 %) wore mask **Spill management** 205 (82 %) used a spill kit Handling bodily fluids n = 238 (95 %) 228 (96 %) wore gloves 55 (23 %) wore gown 5 (2 %) wore goggles 7 (3 %) wore mask
Menonna-Quinn et al., 2019 (United States)	To examine the use of personal protective equipment among inpatient and outpatient nurses while	Cross-sectional study Self-administered 'Hazardous drug handling' questionnaire (adapted from Polovich and Martin,	N = 94 oncology nurses; n = 27 inpatient, n = 67 outpatient, attended 3-day oncology course 170 questionnaires	Education and professional development n = 27 Inpatient 6 Oncology Certified Nurse 1 Advanced Oncology Certified	Administration 65 (69 %) used Closed System drug-Transfer Device (CSTD) 77 (82 %) wore chemotherapy gloves

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
	administering hazardous chemotherapy agents	2011 and modified by Callahan et al., 2016)	distributed, 55 % response rate	Nurse 1 Advanced Oncology Certified Clinical Nurse Specialist n = 67 outpatient 24 Oncology Certified Nurse 1 Advanced Oncology Certified Nurse 1 Advanced Oncology Certified Clinical Nurse Specialist 1 nurse practitioner	29 (31 %) wore double gloves 44 (47 %) wore gown 1 (1 %) wore eye protection 15 (16 %) wore respirator mask Disposal 70 (74 %) wore chemotherapy gloves 19 (20 %) wore double gloves 29 (31 %) wore gown 4 (4 %) wore eye protection 12 (13 %) wore respirator mask Handling bodily fluids 16 (17 %) wore chemotherapy gloves 23 (24 %) wore gown 0 (0) wore eye protection 11 (12 %) wore respirator mask
Momeni et al., 2013 (Iran)	To determine the acute and chronic adverse effects experienced by nurses working in chemotherapy units and their proper use of personal protective equipment	Cross-sectional study Self-administered questionnaire (newly developed) and unannounced observation visits	N = 63 chemotherapy nurses; inpatient and outpatient. 79 nurses invited, response rate 80 % Data on personal protective equipment use reported here	Education and professional development n (%) Median [interquartile range] 57 (90 %) Median 10 [9] hours of education on preparation 47 (75 %) Median 6 [10] hours of education on the management of cytotoxic wastes	Preparation 63 (100 %) used class I biological safety cabinets (not suitable for cytotoxic drugs) Only hospitals had dedicated preparation rooms Overall handling (not differentiated into activity) 38 (60 %) used all personal protective equipment 14 (22 %) wore 3 items 2 (3 %) did not use personal protective equipment 60 (95 %) wore gloves 46 (73 %) wore gown 45 (71 %) wore glasses 57 (90 %) wore mask
Nieweg et al., 1994 (Netherlands)	To establish what protective measures Dutch nursing staff employ in practice and what they know about antineoplastic drugs	Cross-sectional study Self-administered questionnaire (newly developed, based on self-study modules, Dunne, 1989 and Oncology Nursing Society (ONS), 1989	N = 824 administer antineoplastic drugs; inpatient. 1373 questionnaires distributed in 10 hospitals, response rate 60 %	Policies and guidelines 725 (88 %) wards had guidelines on safe handling Knowledge of the risk 775 (94 %) agree protective measures effective 618 (75 %) agree possible contamination during preparation, administration and handling excreta 99 (12 %) agree contamination possible while washing a patient 634 (77 %) recognise when splashes and aersolisation can happen 321 (39 %) latex gloves greater protection than polyvinyl chloride (PVC) 396 (48 %) permeability of gloves increases after 30 min 659 (80 %) excreta contain large doses of antineoplastics Spill management 742 (90 %) should wear gloves 453 (55 %) gown should also be worn	Administration 280 (34 %) attached infusion bottle or bag while hanging 750 (91 %) wore gloves 173 (21 %) wore gown 148 (18 %) wore mask 25 (3 %) wore googles 742 (90 %) washed hands after Disposal 791 (96 %) material deposited in special container 750 (91 %) container tightly closed and clearly marked **Handling bodily fluids** 544 (66 %) wore gloves 132 (16 %) wore gown 99 (12 %) wore mask
Nwagbo et al., 2017 (Nigeria)	To assess nurses' knowledge of chemotherapy and occupational safety practices in the oncology unit	Cross sectional study Questionnaire (newly developed)	N = 100 administer chemotherapy, in oncology units in the University College hospital. 105 in sample, total population size unknown	Education and professional development Certified oncology diploma program has only recently started in Abuja, Nigeria (the only one at time of study) Knowledge of the risk Preparation 96 (96 %) gloves should be	Preparation 20 (20 %) in special room Spill management 73 (73 %) prevention of spills 73 (73 %) handle spills by cleaning Overall handling (not differentiated into activity) Preparation, administration

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				worn 76 (76 %) a facemask should be worn 88 (88 %) in special room Administration 96 (96 %) gloves should be worn 76 (76 %) a facemask should be worn 85 (85 %) gowns should be worn Spill management 92 (92 %) gloves should be worn 26 (26 %) not certain of recommendations 40 (40 %) not certain how to handle stained clothes or sheets	and cleaning of spills 84 (84 %) wore gloves 21 (21 %) wore protective apron or overall 25 (25 %) wore mask and goggles
Orujlu et al., 2016 (Iran)[a]	To evaluate knowledge, attitude, and performance of nurses during the administration of antineoplastic drugs, chemotherapy workload and the experienced side effects	Cross-sectional study Two self-administered questionnaires (adapted from previous studies) The data on knowledge, attitude and practice is reported	N = 54 oncology nurses; n = 16 outpatient, n = 38 inpatient	Policies and guidelines 28 (52 %) had safety-handling guidelines Education and professional development 27 (64 %) had training from different sources Knowledge of the risk Mean 9.43 (± 1.5) (0–12) Attitude or factor affecting knowledge and practice Attitude Mean 39.14 (± 6.5) (15–60)	Preparation 54 (100 %) used biological safety cabinet 32 (59 %) wore double gloves 25 (46 %) wore gown 46 (85 %) wore respirator 20 (37 %) wore eye protection Administration 29 (54 %) wore double gloves 18 (33 %) wore gown 50 (93 %) wore respirator 9 (17 %) wore eye protection Disposal 40 (74 %) wore double gloves 19 (35 %) wore gown 11 (20 %) wore eye protection 28 (52 %) wore respirator Spill management 23 (43 %) wore double gloves 17 (32 %) wore gown 11 (20 %) wore eye protection 28 (52 %) wore respirator Overall handling (not differentiated into activity) Performance Mean 13.41 (± 4.7) (0–23)
Pirot et al., 2023 (France)[a]	To assess the impact of the lack of knowledge on risk perception and on protective practices related to the handling of home-based chemotherapy by home nurses	Cross-sectional study Interviewer-administered questionnaire (adapted from Benoist et al., 2022a, 2022b, risk perception questions adapted from Hon et al., 2015). Questions available	N = 28 chemotherapy nurses; home nurses. Population size unknown, worked in collaboration with two hospitals	Education and professional development 9 (32 %) had initial training handling antineoplastic drugs 11 (39 %) had ongoing training 14 (50 %) had training more than 11 years ago Knowledge of the risk 4 (14 %) scored above 50 % on locations of contamination 14 (50 %) risk management knowledge above 50 % Attitude or factor affecting knowledge and practice 25 (89 %) agree risk of exposure very low 3 (11 %) all antineoplastic drugs have the same level of toxicity 22 (79 %) protective measures reduce the risk 13 (46 %) trust management about the risk 20 (71 %) personal protective equipment suitable	Administration n = 26 9 (35 %) administered antineoplastic drugs 26 (100 %) removed infusions Disposal 16 (57 %) collected waste and stored in their home office Overall handling (not differentiated into activity) n = 26 14 (54 %) wore nitrile gloves 20 (77 %) wore gown 1 (4 %) wore glasses 26 (100 %) wore mask

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
Polovich and Clark, 2012 (United States)	To examine relationships among factors affecting nurses' use of hazardous drug safe-handling precautions, identify factors that promote or interfere with hazardous drug precaution use, and determine managers' perspectives on the use of hazardous drug safe-handling precautions	Cross-sectional study Self-administered 'Revised hazardous drug handling questionnaire' (adapted from Martin and Larson, 2003, Gershon et al., 2007, Gershon et al., 1995, Geer et al., 2006, Geer et al., 2007, McCullagh et al., 2002) and telephone interviews with managers	N = 185 oncology nurses; n = 165 handle chemotherapy in the last year, n = 20 managers (19 nurses, 1 radiation therapist). Population from association of community cancer centres, 359 nurses sent questionnaire, response rate 46 % and 52 managers contacted, response rate 38 %. Workplace safety climate questions available	Policies and guidelines n = 20 managers 20 (100 %) had written policies Education and professional development n = 20 managers 16 (80 %) had orientation programs 12 (60 %) used a skill checklist during orientation Knowledge of the risk n = 165 Chemotherapy Exposure Knowledge Mean 10.9 (± 1.07) (0–12) Attitude or factor affecting knowledge and practice **n = 20 managers** 5 (25 %) formal mechanism to monitor compliance 10 (50 %) spot checks 5 (25 %) gowns not provided by employer 5 (25 %) too busy or rushed 4 (20 %) gowns uncomfortable or cumbersome 4 (20 %) lack of concern for exposure 3 (15 %) urgent patient situations 3 (15 %) lack of knowledge 3 (15 %) forgetting Workplace safety climate Mean 92.7 (± 8.6) (21–105) **n = 165 oncology nurses** Self efficacy for using personal protective equipment Mean 20.8 (± 2.96) (6–24) Perceived barriers Mean 21.94 (± 6.50) (13–52) Perceived risk Mean 3.14 (± 0.58) (0–4) Interpersonal influence Mean 2.21 (± 0.44) (0–3) Conflict of interest Mean 1.83 (± 0.62) (1–4) Workplace safety climate Mean 88.39 (± 12.03) (21–105)	Preparation Used biological safety cabinet Mean 4.8 (± 0.87) (0–5) Wore gloves Mean 4.8 (± 0.87) (0–5) Wore double gloves Mean 1.0 (± 1.7) (0–5) Wore gown Mean 3.5 (± 1.9) (0–5) Wore eye protection Mean 1.5 (± 2.0) (0–5) Wore respirator/mask Mean 0.58 (± 1.1) (0–5) Overall Mean 2.7 (± 0.76) (0–5) Administration Wore gloves Mean 4 (± 1.7) (0–5) Wore double gloves Mean 1.2 (±1.9) (0–5) Wore gown Mean 3 (± 2.2) (0–5) Wore eye Protection Mean 1.3 (± 1.7) (0–5) Wore respirator Mean 0.61 (± 1.1) (0–5) Overall Mean 2 (± 1.1) (0–5) Disposal Wore gloves Mean 3.8 (± 1.9) (0–5) Wore double gloves Mean 1.1 (± 1.8) (0–5) Wore gown Mean 2.9 (± 2.2) (0–5) Wore eye Protection Mean 1 (± 1.6) (0–5) Wore respirator Mean 1.9 (± 1.2) (0–5) Overall Mean 1.9 (± 1.2) (0–5) Handling bodily fluids Wore gloves Mean 2.9 (± 2.3) (0–5) Wore double gloves Mean 1.3 (± 1.8) (0–5) Wore gown Mean 1.9 (± 2.1) (0–5) Wore eye protection Mean 1.2 (± 1.8) (0–5) Wore respirator Mean 0.67 (± 1.4) (0–5) Overall Mean 1.6 (± 1.3) (0–5)
Polovich and Martin, 2011 (United States)[a]	To describe the self-reported use of personal protective equipment by oncology nurses while handling hazardous drugs and to assess nurses' knowledge about the latest national guidelines related to hazardous drug safe-handling precautions	Cross-sectional study Self-administered questionnaire 'Hazardous drug handling questionnaire' (adapted from Martin and Larson, 2003)	N = 330 prepared chemotherapy, administered chemotherapy, or both. Population of 400 nurses at 3 education sessions, 335 questionnaires returned (5 excluded) response rate 84 %	Policies and guidelines 294 (89 %) written policies and procedures regarding hazardous drug handling Education and professional development 155 (47 %) received information regarding the 2004 NIOSH alert (National Institute for Occupational Safety and Health) Certification: 202 (61 %) Oncology Certified Nurse 13 (4 %) Advanced Oncology Certified Nurse 1 (<1 %) Advanced Oncology Certified Clinical Nurse Practitioner	Preparation 151 (46 %) by pharmacists 66 (20 %) pharmacy technicians 115 (35 %) by nurses n = 113 113 (100 %) wore gloves 12 (11 %) wore double gloves 70 (62 %) wore gown 66 (58 %) reused gowns 28 (25 %) wore eye protection 11 (10 %) wore respiratory protection 17 (15 %) wore lab coat Administration n = 311 299 (96 %) wore gloves 56 (18 %) wore double glove 162 (52 %) wore gown

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				11 (3 %) other 91 (28 %) not certified	118 (38 %) reuse gowns 56 (18 %) wore eye protection 25 (8 %) wore respiratory protection 40 (13 %) wore lab coat Disposal n = 312 300 (96 %) wore gloves 134 (43 %) wore gown 41 (13 %) wore eye protection 19 (6 %) wore respiratory protection Spill management 320 (97 %) spill kit available 297 (90 %) used for most recent spill Handling bodily fluids n = 299 293 (98 %) wore gloves 72 (24 %) wore gown 27 (9 %) wore eye protection 9 (3 %) wore respiratory protection
Rizalar et al., 2012 (Turkey)[a]	To investigate whether nurses have taken safety measures for personal and environmental protection during chemotherapy preparation and administration	Cross-sectional study Interviewer-administered questionnaire (newly developed) Questions reported	N = 73 nurses handle chemotherapy drugs, population size unknown	Policies and guidelines 39 (53 %) had no guidelines for preparation and administration Education and professional development 28 (38 %) had received training Attitude or factor affecting knowledge and practice Preparation 43 (83 %) no safety cabinet Spill management 9 (12 %) spill kit available	Preparation 52 (71 %) nurses prepared chemotherapy drugs n = 52 52 (100 %) wore gloves 35 (67 %) wore apron 8 (15 %) wore eyeglasses 36 (69 %) wore mask 9 (17 %) ate in chemotherapy room 2 (4 %) smoked in chemotherapy room 6 (11 %) stored food in chemotherapy room 32 (61 %) changed contaminated gloves 30 (57 %) changed perforated gloves 19 (36 %) changed gloves after 30 mins 5 (10 %) changed at the end of therapy Administration 65 (89 %) nurses administer 19 (26 %) administered when pregnant or postpartum 18 (25 %) plastic-backed absorbent pad used n = 52 52 (100 %) wore gloves 28 (54 %) wore apron 13 (25 %) wore eyeglasses 0 (0 %) wore mask Disposal 32 (44 %) put protective materials in general waste 17 (23 %) put sharp items in general waste 40 (55 %) used covered medical waste container Spill management 35 (48 %) had spillage of a drug 60 (82 %) had accidental contamination n = 60 33 (55 %) took off clothes if contaminated

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					18 (30 %) washed hands with water and soap 7 (12 %) took off clothes and wash hands 2 (3 %) did no particular action for spill 0 (0 %) informed the employee's manager about the accident 0 (0 %) reported incident to supervisor Handling bodily fluids 14 (19 %) put contaminated sheets into labelled washing 19 (26 %) used waterproof bed cover 36 (49 %) used no precautions Overall handling (not differentiated into activity) 52 (71 %) used protective measures
Rogers, 1987 (United States)	To report the influences of work practices, methods of handling antineoplastic agents and the use of personal protective equipment on mutagenic urine activity, symptomatic complaints and spontaneous abortions	Cross-sectional study and participant diary Interviewer-administered questionnaire (newly developed), individual daily log of handling activities and personal health information, and two urine samples	N = 123; n = 59 oncology, n = 64 unexposed from community health care. 165 invited to participate, 126 oncology nurses responded, response rate 75 % (64 excluded); 180 unexposed invited, 117 responded, response rate 65 % (53 excluded) Data on oncology nurses' work practices reported here		n = 59 Preparation 12 (20 %) only wore gloves for nitrogen mustard preparation Laminar flow hoods not used 28 (47 %) both prepared and administered antineoplastic agents: 4 (14 %) worked in hospital unit 12 (43 %) worked in oncology clinic 12 (43 %) worked in private office Administration 31 (53 %) administered only 15 (48 %) worked in hospital unit 16 (52 %) worked in oncology clinic 0 (0 %) worked in private office Disposal Agents 28 (47 %) returned to Pharmacy 13 (22 %) with usual trash 8 (14 %) poured down sink or toilet 8 (14 %) separated from usual trash Equipment 40 (68 %) discarded with usual trash 19 (32 %) separated from usual trash Overall handling (not differentiated into activity) 24 (40 %) sometimes wore gloves; 18 (75 %) had only been doing this for less than 12 months 8 (14 %) sometimes wore protective clothing 5 (8 %) sometimes wore mask
Silver et al., 2016 (United States)[a]	To examine associations between a number of worker and workplace characteristics and three endpoints: personal	Cross-sectional study Self-administered online 'NIOSH health and safety practices survey of healthcare workers -	N = 1094 oncology nurses; administered antineoplastics in the last week and employed in hospitals, n varied for	Policies and guidelines 1042 (95 %) procedures for safe administration 850 (78 %) familiarity with guidance documents –	Administration 494 (48 %) used Closed System drug-Transfer Device (CSTD) 961 (93 %) used needleless

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
	protective equipment use; activities performed with gloves previously worn to administer antineoplastic drugs; and spills of liquid antineoplastic drugs	administration of antineoplastic drugs module' questionnaire (newly developed) Data available	individual items. Population members of professional practice organisations	American Society of Health-System Pharmacists (ASHP), National Institute for Occupational Safety and Health (NIOSH), Oncology Nursing Society (ONS) or Occupational Safety and Health Administration (OSHA) Education and professional development 1041 (95 %) trained 715 (66 %) trained in the last year Attitude or factor affecting knowledge and practice 973 (92 %) personal protective equipment available 898 (86 %) had enough time for safety precautions 661 (63 %) staffing adequate	system 984 (95 %) used luer-lock fittings 953 (87 %) wore at least one pair chemotherapy gloves 252 (23 %) wore double gloves 715 (65 %) wore gown Use of personal protective equipment (gloves, gown, double gloves) Mean 1.76 (± 0.86) (0–3) **n = 1045 administer liquid antineoplastics** 146 (14 %) wore face/eye protection Use of personal protective equipment for liquids (gloves, gown, double gloves, mask) Mean 1.94 (±0.95) (0–4) n = 352 primed intravenous tubing themselves 58 (17 %) with antineoplastic drugs Spill management n = 1044 99 (9 %) liquid spill past week Overall handling (not differentiated into activity) n = 1089 activities performed with gloves that had been used to administer antineoplastic drugs 716 (66 %) touched intravenous pump or bed controls 297 (27 %) touched waste basket/garbage bags 249 (23 %) used pen or pencil 218 (20 %) touched door knobs, cabinets, or drawers 138 (13 %) touched a computer keyboard, mouse, monitor, or calculator 115 (11 %) handled files or charts 73 (7 %) used a non-disposable stethoscope 40 (4 %) used phone/cell phone/pager 22 (2 %) ate, drank, chewed gum, or smoked 3 (<1 %) used restroom 2 (<1 %) applied cosmetics
Srisintorn et al., 2021 (Thailand)[a]	To explore factors associated with personal protective equipment use by nurses and nurse assistants while performing tasks where antineoplastic drug exposure may occur	Cross-sectional study Self-administered 'Hazardous drug handling questionnaire' (adapted from Polovich and Clark, 2012 and translated), questions and results reported	N = 884 nursing staff perform antineoplastic drug related tasks; n = 499 nurses, n = 385 nurse assistants. 1326 questionnaires distributed and 1043 returned (159 excluded), response rate 79 %	Education and professional development 565 (66 %) had no training 119 (14 %) had 1–2 days training 172 (20 %) had >2 days training Knowledge of the risk Median [interquartile range Q1, Q3] (scale range) Knowledge about AD exposure (n = 884) Median 10 [8, 11] (0–12) Attitude or factor affecting knowledge and practice Median [interquartile range Q1, Q3] (scale range)	Preparation Prepared by pharmacy Spill management n = 373 nurses 178 (48 %) wore gown 323 (87 %) wore single/inner gloves 209 (56 %) wore double gloves 108 (29 %) wore googles/ face shield 332 (89 %) wore respirator n = 294 nurse assistants 32 (19 %) wore gown 217 (74 %) wore single/inner gloves 141 (48 %) wore double

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Self-efficacy about using personal protective equipment (n = 865) Median 17 [15, 19] (6–24) Barriers to using personal protective equipment (n = 841) Median 27 [22, 30] (13–52) Perceived risk of antineoplastic drug exposure (n = 867) Median 10 [9, 12] (3–12) Interpersonal influence—Model (n = 864) Median 7 [5, 9] (0–12) Interpersonal influence—Norm (n = 850) Median 8 [4, 8] (0–12) Conflict of interest about using personal protective equipment (n = 874) Median 12 [9, 14] (6–24) Workplace safety climate (n = 843) Median 78 [69, 84] (21–105)	gloves 105 (36 %) wore googles/face shield 220 (75 %) wore respirator Handling bodily fluids n = 378 nurses (urine) 286 (76 %) wore single/inner gloves 62 (16 %) wore double gloves 34 (9 %) wore gown 7 (2 %) wore googles/face shield 261 (69 %) wore respirator n = 345 nurse assistants (urine) 260 (75 %) wore single/inner gloves 95 (28 %) wore double gloves 42 (12 %) wore gown 15 (4 %) wore googles/face shield 226 (66 %) wore respirator Overall handling (not differentiated into activity) n = 465 nurses (handling) 337 (72 %) wore single/inner gloves 80 (17 %) wore double gloves 57 (12 %) wore gown 6 (1 %) wore googles/face shield 350 (75 %) wore respirator n = 171 nurse assistants (handling) 105 (61 %) wore single/inner gloves 33 (19 %) wore double gloves 32 (19 %) wore gown 20 (12 %) wore googles/face shield 102 (59 %) wore respirator
Stajich et al., 1986 (United States)[a]	Assess the protective measures Registered Nurses use to handle parenteral antineoplastic agents in oncologist practices	Cross-sectional study Self-administered questionnaire (newly developed)	N = 33 oncology nurses; outpatient. Response rate 54 %	Education and professional development 18 (55 %) had special training	Preparation 16 (49 %) wore gloves 3 (9 %) wore masks 1 (3 %) wore protective outer garments 4 (12 %) wore glasses 3 (9 %) used hoods Administration 5 (15 %) wore gloves 1 (3 %) wore mask 1 (3 %) wore protective outer garments Disposal 9 (27 %) used special disposal procedures Spill management 11 (33 %) used special spill/clean up procedures; 9 (82 %) followed recommended guidelines Overall handling (not differentiated into activity) 10 (30 %) used proper labelling
Türk et al., 2004 (Turkey)	To evaluate the level of knowledge of nurses on the health effects and exposure of cytotoxic drugs; to describe the protective measures for handling these agents; to determine the influence of this knowledge	Cross-sectional study Two self-administered questionnaires (newly developed) and direct observation	N = 120 nurses handle cytotoxic drugs. Population of 137 nurses, response rate 87 %	Education and professional development 37 (31 %) completed a training program Knowledge of the risk Mean 61.3 (± 17.1) (0–88)	Preparation 39 (33 %) used biological safety cabinet 54 (45 %) had proper aspiration system 117 (97 %) wore gloves 27 (23 %) wore working suit 104 (87 %) wore surgical

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
	on their clinical attitudes, behaviour and actual usage of safety measures				mask 6 (5 %) wore goggles 5 (4 %) wore all personal protective equipment Disposal 18 (15 %) disposed of waste properly Handling bodily fluids Change bed sheets, nasogastric tube and urinary catheters 84 (70 %) wore gloves 2 (2 %) wore working suit 32 (27 %) wore surgical mask 1 (1 %) wore goggles Overall handling (not differentiated into activity) Behaviour in drug handling area 60 (50 %) drank beverages 52 (43 %) stored food and beverages 49 (41 %) ate food 8 (7 %) used cosmetics 5 (4 %) smoked
Valanis and Browne, 1985 (United States)	To determine the extent to which protective measures are used by nurses while handling antineoplastic drugs, to characterise the patterns of drug handling, and to ascertain the major sources of exposure perceived by the nurses	Cross-sectional study Self-administered questionnaire (newly developed, pilot)	N = 67 handled antineoplastic drugs. Population total unknown		Preparation 57 (85 %) prepared antineoplastic drugs 2 (3 %) used protected area in designated room 9 (13 %) used undesignated room 3 (5 %) used horizontal laminar flow hood 64 (95 %) no flow hood used 12 (19 %) always used gloves 3 (5 %) always used reusable lab coat 0 (0 %) always used eye googles 0 (0 %) always used a mask Disposal 33 (49 %) poured left over drugs down the drain 13 (19 %) used special receptacles for waste 6 (9 %) double bagged waste Spill management 49 (74 %) at least occasional spillage on clothing (25 % of the time or more) 58 (87 %) at least occasional skin contact (25 % of the time or more) n = 58 13 (23 %) spill occurred during connection/ disconnection with butterfly 13 (23 %) general spillage 9 (15 %) due to pressure in vial 8 (14 %) due to bad connection 6 (10 %) when removing air from syringe 5 (8 %) due to needle coming off syringe 5 (8 %) when drug mixing and drawing up Handling bodily fluids 21 (31 %) had daily contact with excreta Overall handling (not

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					differentiated into activity 47 (70 %) prepared and administered the drugs Preparation 13 (2 %) only prepared antineoplastic drugs 310 (49 %) both prepared and administered antineoplastic drugs 480 (76 %) wore gloves 228 (36 %) wore gowns 367 (58 %) wore lab coat 32 (5 %) wore goggles 95 (15 %) wore mask 1 in 4 flow hoods available horizontal rather than vertical **Administration** 316 (50 %) wore gloves 88 (14 %) wore gown 322 (51 %) wore lab coat 6 (1 %) wore goggles 38 (6 %) wore mask Spill management n = 310 62 (20 %) had never had skin contact while mixing 202 (65 %) had skin contact less than 25 % of the time The usual response to skin contact was washing with soap and water Overall handling (not differentiated into activity) Improvement of glove use (INPATIENT, OUTPATIENT) 1981 Never (184 (42 %) inpatient, 249 (54 %) outpatient) 1985 Never (44 (7 %) inpatient, 57 (9 %) outpatient)
Valanis and Shortridge, 1987 (United States)	To examine the use of protection among nurses in 1985, compared to findings with data from the 1981 study by Crudi et al., and examine the reasons given for not using protection	Cross-sectional and cohort study (compare results to previous study) Questionnaire published in Oncology Nursing Forum (newly developed)	N = 632 oncology nurses, prepared or administered antineoplastic drugs	Attitude or factor affecting knowledge and practice Reasons for not using protection: 209 (33 %) inconvenience of using protective garments 158 (25 %) did not believe there is a personal danger 88 (14 %) protective clothing or equipment not available 76 (12 %) use is deemed inappropriate 32 (5 %) not aware of the hazards 57 (9 %) protective garments upset patients 13 (2 %) not mandated by institutional policy	
Valanis et al., 1991 (United States)	To examine the relationship between protective practices mandated by institutional policies and use of protection among staff who handle antineoplastic drugs in healthcare facilities	Cross-sectional 3-phase study Content analysis of antineoplastic drug handling policies and self-administered questionnaire (based on Occupational Safety and Health Administration (OSHA) guidelines, 1986	N = 125 participants; 7 physicians, 22 pharmacy staff, n = 93 nurses oncology; 11 Hospitals and 1 private practice provided policies. Population number unknown Nurses' data is reported here	Policies and guidelines Having an antineoplastic drug handling policy was necessary for inclusion in this study Attitude or factor affecting knowledge and practice n = 22 preparation 15 (68 %) mask use not required for preparation in facility's guidelines 2 (9 %) mask not necessary n = 15 6 (40 %) gown use not required 2 (13 %) gown not necessary n = 87 administration 10 (11 %) unaware not wearing gloves is hazardous 8 (9 %) too awkward to wear gloves 6 (7 %) not required to wear gloves 5 (6 %) too time consuming to wear gloves 3 (3 %) not necessary to wear gloves Not using gloves and gowns for patient care and handling body fluids Not required by policy Unaware that non-use is hazardous	Preparation n = 23 4 (16 %) wore mask 21 (91 %) wore gloves 9 (41 %) wore gown 2 (10 %) wore goggles Administration n = 87 68 (78 %) wore gloves 11 (12 %) wore gown 6 (7 %) wore mask 2(3 %) wore goggles Disposal n = 85 76 (89 %) wore gloves 31 (37 %) wore gown) 15 (18 %) wore goggles Mask use for disposal not in Occupational Safety and Health Administration (OSHA) therefore not included in study Spill management n = 77 48 (63 %) wore gloves 10 (13 %) wore gown Goggles use not in Occupational Safety and Health Administration (OSHA) therefore not included in study

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Interferes with staff's relationships with patients	Mask use not in Occupational Safety and Health Administration (OSHA) guidelines therefore not included in study Overall handling (not differentiated into activity) n = 84 (patient care) 16 (19 %) wore gloves 6 (7 %) wore gown Preparation n = 397, 'n' each work setting unknown Used vertical flow hood 72 % of those working in outpatient settings 44 % of those working in large hospital 66 % of those working in small hospital Wore gloves 81 % of those working in outpatient settings 88 % of those working in large hospital 98 % of those working in small hospital Wore gown 31 % of those working in outpatient settings 53 % of those working in large hospital 68 % of those working in small hospital Administration n = 1654, 'n' each work setting unknown Wore gloves 67 % of those working in outpatient settings 86 % of those working in large hospital 87 % of those working in small hospital Wore gown 24 % of those working in outpatient settings 23 % of those working in large hospital 21 % of those working in small hospital Handling bodily fluids n = 2119 nurses and nurse aides, 'n' each work setting unknown Wore gloves 60 % of those working in outpatient settings 78 % of those working in large hospitals 78 % of those working in small hospitals Wore gown 10 % of those working in outpatient settings 6 % of those working in large hospitals 4 % of those working in small hospitals Overall handling (not differentiated into activity) Reasons for changes from pre to post 1988 was the
Valanis et al., 1992 (United States)	Compare current handling activities and use of protection by profession, work setting and time	Cross-sectional study Self-administered questionnaire (adapted from Valanis and Browne, 1985 and Crudi et al., 1982)	N = 4659 exposed and unexposed nurses; n = 397 nurses prepare antineoplastic drugs, n = 1654 administer, n = 2119 handle excreta from hospitals, outpatient clinics, private doctor offices. Population from member institutions of the National surgical adjuvant breast and bowel project (NSABP), 8566 questionnaires sent, response rate 56 % (4797)		

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
					introduction of anticancer drug handling regulations, and changes for handling excreta due to acquired immunodeficiency syndrome (AIDS) precautions
Walton et al., 2020 (United States)	To describe inpatient oncology surfaces most contaminated with antineoplastic drugs and to characterise personal protective equipment use and factors that predict its use among inpatient oncology staff.	Cross-sectional study Surface sampling and self-administered online 'Revised hazardous drug handling' questionnaire (Polovich and Clark, 2012) Data from corresponding author	N = 27 nursing staff, n = 25 nurses, n = 2 nursing assistants. Population size unknown, completion rate given as 73 %.	Education and professional development 26 (96 %) orientation given on starting in oncology ward 24 (89 %) completed annual refresher Attitude or factor affecting knowledge and practice Data not reported for perceived barriers, perceived risk, self-efficacy, safety climate, interpersonal influence and conflict of interest	Mean (scale range) Administration All personal protective equipment use and protective behaviour Mean 2.81 (0–5) Use of Closed System drug-Transfer Device (CSTD) Mean 1.79 (0–5) Chemotherapy gloves Mean 3.24 (0–5) Double gloves Mean 4.44 (0–5) Gown Mean 4.74 (0–5) Eye protection Mean 0.27 (0–5) Mask Mean 2.0 (0–5) Disposal All personal protective equipment used and protective behaviour Mean 2.62 (0–5) Chemotherapy gloves Mean 3.40 (0–5) Double gloves Mean 3.65 (0–5) Gown Mean 3.73 (0–5) Eye protection Mean 0.24 (0–5) Mask Mean 1.85 (0–5) Handling bodily fluids All personal protective equipment use and protective behaviour Mean 1.77 (0–5) Chemotherapy gloves Mean 3.36 (± 2.31) (0–5) Used plastic-backed pads while flushing Mean 1.77 (0–5) Double gloves Mean 1.44 (0–5) Gown Mean 1.04 (0–5) Eye protection Mean 0.58 (0–5) Mask Mean 2.17 (0–5)
Zayed et al., 2019 (Egypt)[a]	To assess the knowledge, attitude, and practice (KAP) of oncology nurses towards the safe handling of cytotoxic drugs	Cross-sectional study Self-administered questionnaire (adapted from Alehashem and Baniasadi, 2018) and observational checklist	N = 55 oncology nurses; handling cytotoxic drugs for 1 + years. Reported response rate 100 %	Policies and guidelines 43 (78 %) know guidelines and standards Education and professional development 30 (55 %) had received formal training **Knowledge of the risk** 16 (29 %) know correct use of biological safety cabinet 41 (75 %) safe administration knowledge 45 (82 %) safe disposal knowledge 21 (38 %) spill management knowledge Overall Mean 19.05 (± 4.8) (0–26) Attitude or factor affecting	Preparation Observational checklist n = 12 10 (83 %) wore gloves 7 (58 %) wore gown 0 (0 %) wore eye protection 9 (75 %) wore mask 10 (83 %) washed hands before 11 (92 %) washed hands after Administration Observational checklist n = 35 29 (83 %) wore gloves 9 (26 %) wore gown 0 (0 %) wore eye protection 31 (89 %) wore mask 27 (77 %) washed hands before 23 (66 %) washed hands after

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				knowledge and practice Mean 13.09 (± 3.07) (0–16)	**Disposal** Observational checklist n = 55 23 (42 %) wore gloves 10 (18 %) wore gown 0 (0 %) wore eye protection 19 (35 %) wore mask 0 (0 %) washed hands before 41 (75 %) washed hands after Spill management Observational checklist n = 5 5 (100 %) wore gloves 3 (60 %) wore gown 0 (0 %) wore eye protection 3 (60 %) wore mask 0 (0 %) washed hands before 5 (100 %) washed hands after Handling bodily fluids Observational checklist n = 55 23 (42 %) wore gloves 10 (18 %) wore gown 0 (0 %) wore eye protection 19 (35 %) wore mask Overall handling (not differentiated into activity) Overall practice Mean 8.87 (± 1.35) (0–12)
Cross sectional and cohort studies - operating theatre setting					
Benoist et al., 2022a, 2022b (France)	To compare the differences in perception and knowledge of the risks associated with the practice of hyperthermic intraperitoneal chemotherapy (HIPEC) and pressurised intraperitoneal aerosol chemotherapy (PIPAC), training, protection practices and occupational exposures of all surgical staff	Cross-sectional study Interviewer-administered questionnaire (newly developed)	N = 51 participants; n = 20 operating room nurses, n = 21 auxiliary caregivers, n = 10 medical staff. Population of healthcare professionals 54, response rate 94 % The operating nurses' data is reported here	Education and professional development 2 (10 %) Training on the handling of antineoplastic drugs (nursing school) 2 (12 %, n = 17) ongoing training for hyperthermic intraperitoneal chemotherapy (HIPEC) and pressurised intraperitoneal aerosol chemotherapy (PIPAC) Knowledge of the risk 3 (15 %) fear of handling antineoplastic drugs 4 (20 %) the toxicity risk level is the same for all antineoplastic drugs 15 (75 %) safety measures reduce risk 4 (24 %, n = 17) very low risk exposure for hyperthermic intraperitoneal chemotherapy (HIPEC) 9 (53 %, n = 17) very low risk exposure for pressurised intraperitoneal aerosol chemotherapy (PIPAC) Potential contamination (n = 17) Injectable route 7 (35 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 2 (12 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC) Cutaneous route 17 (100 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 10 (59 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC)	Spill management 3 (15 %) not aware of correct procedure for accidental exposure Overall handling (not differentiated into activity) 8 (47 %) (n = 17) always wear a gown for hyperthermic intraperitoneal chemotherapy (HIPEC) 16 (94 %) (n = 17) always wear a gown for pressurised intraperitoneal aerosol chemotherapy (PIPAC)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Ocular route 15 (35 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 7 (35 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC) Operating table 16 (94 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 11 (65 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC) Floor 17 (100 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 12 (71 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC) Attitude or factor affecting knowledge and practice 7 (35 %) confident to handle risk of exposure 12 (71 %) (n = 17) protective equipment is suitable for hyperthermic intraperitoneal chemotherapy (HIPEC) 16 (94 %) (n = 17) protective equipment is suitable for pressurised intraperitoneal aerosol chemotherapy (PIPAC)	
Clerc et al., 2021 (International)	To assess the risk perception and the uptake of measures preventing environment-related risks in the operating room during hyperthermic intraperitoneal chemotherapy (HIPEC) and pressurised intraperitoneal aerosol chemotherapy (PIPAC).	Cross-sectional study Self-administered questionnaire (adapted from Al Hosni et al., 2020), questions in supplementary information. Only data on nurses reported	N = 211 operating room team members; n = 68 surgeon, n = 45 anaesthetist, n = 31 anaesthetic nurse, n = 49 scrub nurse, n = 18 cleaning staff. All eligible centres participated (n = 10) in six countries, population size unknown. Only the anaesthetic and scrub nurses' data reported	Policies and guidelines 12 items of personal protective equipment reported (although all 12 items are not necessary at the same time) Education and professional development Overall participation in training 17 (56 %) scrub nurses 28 (55 %) anaesthetic nurses 5 (n = 10) educational sessions for both hyperthermic intraperitoneal chemotherapy (HIPEC) and pressurised intraperitoneal aerosol chemotherapy (PIPAC) procedures Willingness for supplementary information 27 (87 %) anaesthetic nurses 44 (90 %) scrub nurses Knowledge of the risk Anaesthetic nurse (n = 31) 13 (42 %) aerosol risk 6 (19 %) spilling/splashing risk 6 (20 %) risk from contamination of surfaces 6 (20 %) risk from waste manipulation Scrub nurse (n = 49) 22 (45 %) aerosol risk 8 (16 %) spilling/splashing risk 8 (16 %) risk from contamination of surfaces 11 (23 %) risk from waste manipulation Attitude or factor affecting knowledge and practice	Overall handling (not differentiated into activity) Use of all protective measures Anaesthetic nurses (n = 31) 15 (48 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 14 (45 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC) Scrub nurse (n = 49) 28 (58 %) hyperthermic intraperitoneal chemotherapy (HIPEC) 28 (58 %) pressurised intraperitoneal aerosol chemotherapy (PIPAC)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				Perceived level of contamination risk (0–10) Scrub nurses Mean 4.47 (± 0.64) hyperthermic intraperitoneal chemotherapy (HIPEC) Mean 3.43 (± 0.65) pressurised intraperitoneal aerosol chemotherapy (PIPAC)	
Ethnographic and exploratory studies					
Batista et al., 2021 (Brazil)	To understand, from a worker's health perspective, the knowledge of nursing professionals about the use of antineoplastic drugs in a general hospital	Descriptive exploratory study Semi-structured interviews	N = 35 medical surgical, paediatric, intensive care unit nurses; inpatient, outpatient, psychosocial care. Recruitment by snowballing technique	Knowledge of the risk 5 (14 %) no knowledge related to antineoplastic drugs 7 (20 %) could not say what the effects were 35 (100 %) use personal protective equipment as a protective measure The effects on the worker's health: 13 (37 %) skin, mucous membrane and eye irritation 8 (23 %) respiratory and airway problems 4 (11 %) can cause cancer 3 (9 %) infertility, birth defects, abortion 2 (6 %) drugs decrease the professional's immunity Exposure to antineoplastic drugs occurs: 2 (6 %) handling contaminated excreta and/or clothing 9 (26 %) preparation, due to bottle breakage 22 (63 %) disposal, with release and aspiration of drug particles and/or fall onto professional 35 (100 %) administration, through disconnection of the puncture device, loss of access, vial rupture and/or rupture of the infusion lines 28 (80 %) disposal of infusion materials in a dedicated container 15 (43 %) disposal of infusion materials in plastic bags 10 (29 %) disposal of contaminated clothing in plastic bags	Overall handling (not differentiated into activity) 17 (49 %) experienced with antineoplastic drugs 8 (23 %) never had contact with antineoplastic drugs 10 (29 %) if they had contact with antineoplastic drugs they didn't know 32 (91 %) limitation in handling and administering antineoplastic drugs
Chen et al., 2016 (Taiwan)	To explore the concerns of nurses regarding their decision to use or not to use personal protective equipment in the cultural context of Taiwan	An ethnographic study Ethnographic interviews and participant observation, constant comparison method used to generate cultural themes	N = 57 oncology nurses; purposive sampling to reflect the population diversity	Policies and guidelines Written standard operating procedures available for the preparation, administration, disposal and spill management of chemotherapy drugs Attitude or factor affecting knowledge and practice THE LOCAL TRANSFORMATION OF PROFESSIONAL PRACTICES I cannot be a good nurse if I use personal protective equipment Anxiety provoking in patients, disclose a diagnosis, cancer is contagious Efficiency against safety Too time consuming, increased staff:patient ratios, delays administration, personal	Preparation The chemotherapy drugs are prepared by pharmacists

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				protective equipment is cumbersome Professional roles in conflict with social roles Request transfer when pregnant but also need to remain employed INSIDER KNOWLEDGE Good nursing skill becomes the armour to avoid exposure to chemotherapy toxicity Personal protective equipment unnecessary because of skill Encapsulated toxicity The high concentration toxicity is packed into bottles by pharmacists and therefore reduced for nurses Body experiences transformed as evidence for sufficient protection Negative test results is proof of safety HIDDEN COSTS Financial burden Hospital management concerned about the cost Cost containment Limits the use of more expensive personal protective equipment	
Topcu and Beser, 2017 (Turkey)	To describe attitudes, opinions and experiences of nurses administering antineoplastic drugs about safe handling precautions in a smaller country where national guidelines were published less frequently.	Ethnographic study Interviews The components of the Health Belief model was used for analysis	N = 15 oncology clinics. Population of 21 staff, roles unknown	Education and professional development 3 (20 %) had chemotherapy nursing certificate Cues to action Education - one of the factors affecting the use of safe handing precautions most was education; it should be offered before starting work with antineoplastic drugs and regularly repeated later Attitude or factor affecting knowledge and practice Preparation Biological safety cabinet and drug preparation room available Perceived sensitivity Perceived risks - few nurses said that antineoplastic drugs were harmful. Most nurses do not know short or long-term side effects of antineoplastic drugs and only told about their experiences in drug exposures. Vulnerability - friends put them at risk Perceived seriousness Fear - about what may happen Drug exposures - some nurses reported acute effects Perceived benefits Beliefs about safe handling precautions - a nurse believed that safe handling precautions were not protective or had limited protection, several nurses believed that safe handling precautions were protective when they were	**Preparation** Individual factors - all nurses wore gloves but not double or chemotherapy type, personal protective equipment used only for preparation and more careful during preparation Disposal Closed box used

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				used properly and effectively. Safe behaviours - a few nurses emphasised the importance of safe handling standards and commented about their own and their friends' mistakes in preparation and administration of drugs, they admitted that they did not implement safe handling standards. Perceived barriers Organisational factors - heavy workload, staff shortages, over time, safe practices take time, resources not supplied constantly (chemotherapy gloves, closed systems, luer lock connections), unit not considered risky by the organisation Individual factors – 2 (13 %) personal protective equipment creates discomfort in patients therefore not used for administration Cues to action Reminders - importance of written or verbal feedback Safety culture - do what colleagues do	
Educational interventions					
Crickman and Finnell, 2017 (United States)	To implement an evidence-based program that focused on improving the safe handling practices of and reducing the occupational exposure of nurses to hazardous drugs	Quasi-experimental study Pre and post observation 'Assessment tool' for sequence of doffing personal protective equipment and self-administered 'Chemotherapy exposure knowledge' questionnaire (Polovich and Clark, 2012)	N = 31 oncology nurses; inpatient working directly with patients. Population size unknown nurses working in an inpatient oncology unit in Seattle, Washington	Policies and guidelines Implementation of standardised labels for all chemotherapy and other hazardous drugs and messages within the electronic medical record about specific personal protective equipment for nurses to wear Personal protective equipment placed in patient care areas Education and professional development Correct personal protective equipment doffing sequence 30-min educational video intervention Visual tools created to alert staff to personal protective equipment requirements 13 (42 %) current Oncology Certified Nurse 26 (84 %) chemotherapy certification Knowledge of the risk PRE-TEST Mean 10.5 (± 1.09) (0–12) POST-TEST Mean 11.2 (± 0.75) (0–12)	Administration PRE-TEST ASSESSMENT TOOL (n = 9) 9 (100 %) correct personal protective equipment 1 (11 %) correct doffing sequence POST-TEST ASSESSMENT TOOL (n = 10) 10 (100 %) correct personal protective equipment 8 (80 %) correct doffing sequence
Friese et al., 2019 (United States)	To evaluate whether a web-based educational intervention improved personal protective equipment use among oncology nurses who handle hazardous drugs	Cluster randomised control study Self-administered 'Revised drug handling questionnaire' (Polovich and Clark, 2012), Practice environment scale of the nursing work index (Friese, 2012), Safety organising scale (Vogus and Sutcliffe, 2007), Knowledge of hazardous	N = 257 oncology, n = 121 intervention, n = 136 control group. 439 eligible to participate, 62 % completed primary endpoint surveys. Population from 12 academic centre ambulatory oncology settings	Education and professional development Intervention Education online module and quiz for 1 h Knowledge of the risk Personal protective equipment knowledge Intervention PRE-TEST Mean 6.4 (± 1.5) (0–10) POST-TEST Mean 6.5 (± 1.6)	Overall handling (not differentiated into activity) Personal protective equipment use (5 items) Intervention PRE-TEST Mean 2.4 (± 0.8) ((0–5) POST-TEST Mean 2.3 (± 0.9) (0–5) Control PRE-TEST Mean 2.5 (± 0.7) POST-TEST Mean 2.3 (± 0.9)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
		drug handling (newly developed), Occupational dermal survey (Geer et al., 2006)		Control PRE-TEST Mean 6.7 (± 1.8) POST-TEST Mean 6.9 (± 1.5) Attitude or factors affecting knowledge and practice Barriers to personal protective equipment use Intervention PRE-TEST Mean 1.8 (± 0.4) (1–4) POST-TEST Mean 1.8 (± 0.5) (1–4) Control PRE-TEST Mean 2 (± 0.5) (1–4) POST-TEST Mean 1.9 (± 0.5) (1–4)	
Hojati et al., 2023 (Iran)	To determine the effect of teaching chemotherapy safety standards using a smart-phone application on nurses' knowledge, attitude, and performance.	Quasi experimental study Pre-post intervention Interviewer and self-administered knowledge, attitude, and practice (KAP) Questionnaire (adapted from Alehashem and Baniasadi, 2018) at 3 time points	N = 50 chemotherapy inpatient nurses; total chemotherapy nurse population from three hospitals affiliated with Lorestan University of Medical Sciences, 7 nurses excluded	Policies and guidelines Occupational Safety and Health Administration (OSHA) standard guidelines, and Iran's National Standard Organisation Education and professional development Intervention 20 min meeting, then review of the content of a smart phone application for 4 weeks 44 (88 %) had received previous refresher course Knowledge of the risk Before intervention Mean 47.18 (± 8.19) (12–60) Immediately after Mean 60.08 (± 3.82) (12–60) One month after intervention Mean 61.88 (± 3.45) (12–60) Attitude or factors affecting knowledge and practice Attitude Before intervention Mean 30.34 (± 3.94) (8–40) Immediately after Mean 34.32 (± 3.25) (8–40) One month after Mean 34.98 (± 2.88) (8–40)	Overall handling (not differentiated into activity) Performance Before the intervention Mean 43.60 (± 5.11) (13–65) Immediately after Mean 51.78 (± 3.15) (13–65) One month after Mean 52.88 (± 3.06) (13–65)
Jun and Kang, 2023 (South Korea)	To evaluate the effects of safe-handling education on the cognition, practice and stress handling of antineoplastic drugs in clinical nurses	Quasi-experimental study Pre and post 3 questionnaires; cognition and compliance (adapted from Choi et al., 2004) and stress of treatment with anticancer drugs (adapted from Kim, 1996).	N = 60 handle anticancer drugs in surgical or medical ward, n = 30 educational intervention, n = 30 control group. Power analysis 52-person minimum	Policies and guidelines Based on Occupational Safety and Health Administration (OSHA) (Yodaiken and Bennett, 1986) and Korean Society for Oncology Nursing (2008) Education and professional development Pre-test Safety education experience 14 (23 %) experimental group 17 (28 %) control group Intervention 12 h over two weeks, lectures, and practices Knowledge of the risk Total score Experimental PRE-TEST Mean 102.77 (±17.23) (35–140) POST-TEST Mean 132.63 (± 9.91) (35–140) Control PRE-TEST Mean 110.55 (±16.68) (35–140) POST-TEST–TEST Mean	Before the education sessions Preparation Experimental Mean 37.16 (±4.91) (16–64) Control group Mean 34.80 (±7.00) (16–64) Administration Experimental Mean 38.62(± 5.20) (14–56) Control group Mean 37.33 (±3.68) (14–56) Disposal Experimental Mean 12.00(± 1.92) (5–20) Control group Mean 11.17(± 1.76) (5–20) Overall handling (not differentiated into activity) Compliance of safe handling of antineoplastic drug Total score Experimental Mean 86.75(± 9.50) (35–140) Control group Mean 81.93(± 9.47) (35–140)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				115.60 (± 20.44) (35–140) Preparing antineoplastic drugs Experimental PRE-TEST Mean 46.50 (± 9.09) (16–64) POST-TEST Mean 61.17 (± 4.86) (16–64) Control PRE-TEST Mean 50.72 (± 9.10) (16–64) POST-TEST Mean 52.70 (± 11.76) (16–64) Administering antineoplastic drugs Experimental PRE-TEST Mean 42.60 (± 7.56) (14–56) POST-TEST Mean 52.67 (± 4.81) (14–56) Control PRE-TEST Mean 44.10 (± 7.27) (14–56) POST-TEST Mean 46.97 (± 8.50) (14–56) Disposing of antineoplastic drugs Experimental PRE-TEST Mean 13.67 (± 3.64) (5–20) POST-TEST Mean 18.80 (± 1.71) (5–20) Control PRE-TEST Mean 15.47 (± 3.17) (5–20) POST-TEST Mean 15.90 (± 3.10) (5–20) Attitude or factors affecting knowledge and practice Total score stress handling Experimental PRE-TEST Mean 46.57 (± 8.65) (15–60) POST-TEST Mean 42.87 (± 11.39) (15–60) Control PRE-TEST Mean 47.47 (± 11.97) (15–60) POST-TEST Mean 47.49 (± 12.26) (15–60)	
Keat et al., 2013 (Malaysia)	To detect the change of individual nurse's safety-related knowledge and attitude; to detect the change of ward practices in cytotoxic drug handling after a series of pharmacist-based interventions	Quasi-experimental study Pre and post self-administered questionnaire (newly developed) and practice checklist (newly developed)	N = 96 chemotherapy nurses; 15 wards inpatient. Population of nurses unknown, permanent nurses participated	Policies and guidelines Intervention Nurses updated about new Standard Operating Procedure (SOP) by pharmacy staff New cytotoxic drug policy Education and professional development 9 (9 %) formal post-registration training 0 (0 %) pre-registration training Intervention A continuous nurse education session and a cytotoxic drug handling workshop Knowledge of the risk PRE-TEST (n = 96) Hazardous effects Mean 9.2 (± 3.15) (0–25) Ways of exposure to cytotoxic drugs Mean 5.7 (± 2.36) (0–15) Use of personal protective	Practice measured by pharmacist during ward visit Preparation PRE-TEST (n = 96) Mean 0.8 (± 0.86) (0–3) Intervention Initiation of closed-system cytotoxic drug reconstitution services by pharmacists POST-TEST (n = 94) Mean 3.0 (± NA) (0–3) Administration PRE-TEST (n = 96) Mean 1.1 (± 1.25) (0–4) POST-TEST (n = 94) Mean 3.0 (± 0.65) (0–4) Disposal PRE-TEST (n = 96) Mean 1.3 (± 1.1) (0–4) POST-TEST (n = 94) Mean 1.7 (± 1.29) (0–4) Spill management PRE-TEST (n = 96) Mean 1.4 (± 1.12) (0–3)

(*continued on next page*)

Table 2 (*continued*)

Author/s, year (Country)	Aim	Study design and instrument	Sample and setting	Knowledge of risk and safe handling practices, and attitude and factors that affect these	Hazardous drug handling practices
				equipment Mean 5.8 (± 2.34) (0–15) Safe handling measures Mean 24.8 (± 6.4) (0–45) POST-TEST (n = 94) Hazardous effects Mean 15.4 (± 4.65) (0–25) Ways of exposure to cytotoxic drugs Mean 8.6 (± 1.78) (0–15) Use of personal protective equipment Mean 10.6 (± 2.15) (0–15) Safe handling measures Mean 38.8 (± 4.6) (0–45) Attitude or factors affecting knowledge and practice PRE-TEST (n = 96) 53 (55 %) handle cytotoxic drugs safely 51 (53 %) complete personal protective equipment use was unnecessary 43 (45 %) worried about the long-term side effects 72 (75 %) tolerate a certain level of improper practice when busy 58 (60 %) tolerate a certain level of improper practice among peers POST-TEST(n = 94) 75 (80 %) handle cytotoxic drugs safely 25 (27 %) complete personal protective equipment use was unnecessary 90 (96 %) worried about the long-term side effects 32 (34 %) tolerate a certain level of improper practice when busy 26 (28 %) tolerate a certain level of improper practice among peers	POST-TEST (n = 94) Mean 2.7 (± 0.59) (0–3)
Nouri et al., 2021 (Iran)	To determine the effects of standard guidelines education on the safe handling of antineoplastic drugs among oncology nurses	Quasi-experimental study Pre and post-test questionnaire (newly developed) and checklist (newly developed).	N = 32 oncology nurses, population of 35 nurses, response rate 91 %	Policies and guidelines Intervention Educational pamphlet on standard guidelines part of training package Education and professional development Intervention Two-day workshop to deliver training package Knowledge of the risk PRE-TEST Mean 59.5 (± 6.41) (0–37) POST-TEST Mean 66 (± 4.82) (0–37)	Preparation PRE-TEST Mean 0.56 (± 0.09) POST-TEST Mean 0.79 (± 0.06) Administration Drug injection PRE-TEST Mean 0.41 (± 0.10) POST-TEST Mean 0.78 (± 0.07) Disposal PRE-TEST Mean 0.48 (± 0.10) POST-TEST Mean 0.76 (± 0.09) Spill management Drug leakage PRE-TEST Mean 0.07 (± 0.02) POST-TEST Mean 0.50 (± 0.20) Overall handling (not differentiated into activity) Safe handling practices PRE-TEST Mean 18.96 (± 2.54) (0–42) POST-TEST Mean 32.03 (± 2.45) (0–42)

[a] 25 studies included data for both education and professional development, and the practice of wearing gloves for administration or overall handling; higher levels of education/training tend to be associated with higher rates of glove use, and vice versa. An intentional use of unplanned post-hoc data analysis using the Spearman's rank correlation coefficient between education and glove use is 0.639, which is a moderate positive statistically significant correlation (p-value = 0.001). The quantitative data report the 'always' or most positive response category to enable a comparison of results. In Martin and Larson (2003) USUALLY is >50 % of the time. Percentage decimals from the data are rounded to the nearest whole number. Overall handling heading in the 'Hazardous drugs handling practices' column has been used when data refers to general nursing practices. Data are displayed as Mean (± standard deviation) (scale range) i.e. Mean 32.03 (± 2.45) (0–42). N: sample size, n: frequency.

suitable for cytotoxic drugs or were turned off (Momeni et al., 2013; Martin and Larson, 2003).

3.3.2. Administration

The use of personal protective equipment during administration was inconsistent and varied widely across studies, with a range from 0 % to up to 100 % reported for the proportion of nurses who wore gloves, gowns, eye protection and masks (Table 2). Four studies reported that some nurses wore no protection (Ben-Ami et al., 2001; Kyprianou et al., 2010; Chen et al., 2016; Topcu and Beser, 2017). Wearing double gloves, which is wearing one pair of gloves over another, was first reported in the included studies in 2011 (Polovich and Martin, 2011).

A study that compared both glove and gown use by pregnant and non-pregnant nurses reported that neither group always wore these items of personal protective equipment (Lawson et al., 2019). Abbasi et al. (2016) reported there were no clear guidelines for pregnant or lactating nurses, and while pregnant staff did not prepare cytotoxic drugs, they continued to administer and dispose of them. In the study by Rizalar et al. (2012), about a quarter of nurses reported administering chemotherapy when pregnant or postpartum. In another study some nurses reported that they would work in a different environment when pregnant or lactating, or they would seek alternative duties (Graeve et al., 2017). However, sometimes pregnant nurses were not permitted to change work environments (Baykal et al., 2009), they chose to continue working in oncology for financial reasons or resigned (Chen et al., 2016).

Table 3
Quality appraisal of cross-sectional quantitative studies using the 'critical appraisal tool to assess the quality of cross-sectional studies (AXIS)'.

Cross-sectional and cohort studies	1. Were the aims/objectives of the study clear?	2. Was the study design appropriate for the stated aim(s)?	3. Was the sample size justified?	4. Was the target/reference population clearly defined?	5. Was the sample frame taken from an appropriate population base?	6. The sample selection process select appropriate people?	7. Were measures undertaken to address and categorise non-responders?	8. Were the risk factor and outcome variables measured appropriate to the aims?	9. Risk factor and outcome variables instruments trialled, piloted or published?	10. Is it clear what was used to determine statistical significance?	11. Were the methods sufficiently described to enable them to be repeated?	12. Were the basic data adequately described?	13. Does the response rate raise concerns about non-response bias?	14. If appropriate, was information about non-responders described?	15. Were the results internally consistent?	16. Were the results presented for all the analyses described in the methods?	17. Were the authors' discussions and conclusions justified by the results?	18. Were the limitations of the study discussed?	19. Were there any funding sources or conflicts of interest that may affect the interpretation?	20. Was ethical approval or consent of participants attained?
Abbasi et al., 2016	No	Yes	Yes	Yes	Yes	Yes	No	Can't tell	Yes	Yes	No	No	No	Not applicable	No	No	No	No	No	Yes
Abu Sharour et al., 2021	Yes	Yes	No	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes	Yes	Yes	No	Can't tell	Can't tell	Yes	Can't tell	Yes	No	Yes
Al-Azzam et al., 2015	Yes	Yes	No	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes
Alehashem & Baniasadi, 2018	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Can't tell	Yes	Yes	No	No	Yes
Asefa et al., 2021	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	No	Not applicable	Yes	Yes	Yes	Yes	No	Yes
Baykal et al., 2009	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	No	Not applicable	Yes	Can't tell	Yes	No	No	Yes
Ben-Ami et al., 2001	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	No	No	Can't tell
Benoist, Busson et al., 2022	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	No	Not applicable	Yes	Yes	Yes	No	No	Yes
Boiano et al., 2014	Yes	Yes	Can't tell	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	No	Yes
Boiano et al., 2015	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	No	Can't tell	Yes
Brink, 2016 (Dissertation)	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Not applicable	Yes	Yes	No	Not applicable	Yes	Yes	Yes	Yes	No	Yes
Callahan et al. 2016	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Can't tell	Yes	Yes	Yes	No	Yes
Chaudhary 2012	Yes	Yes	No	Yes	Yes	Can't tell	No	Yes	Yes	No	Can't tell	No	Can't tell	No	Yes	Can't tell	Yes	No	Can't tell	Can't tell
Colvin et al., 2016	Yes	Yes	Can't tell	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes
DeJoy et al., 2017	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	Not applicable	Yes	Yes	Yes	Yes	No	Can't tell
Friese et al., 2020	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes
Fuller et al., 2007	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Can't tell	Not applicable	Yes	No	No	Yes	Can't tell	No	No	Yes	No	Can't tell
Goodman, C., 1985	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	No	Not applicable	Yes	Yes	Yes	Not applicable	Yes	Yes	No	Yes	Can't tell	Can't tell
Graeve et al., 2017	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Can't tell	Yes	Yes	Can't tell	Yes
He et al., 2017	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Can't tell	No	Yes	Yes	Yes	Yes	Can't tell	Can't tell
Hon et al., 2015	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	Can't tell	Yes
Jeong et al., 2015	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	Not applicable	Not applicable	Yes	Yes	Yes	No	No	Yes
Karadakovan, A., 1999	Yes	Yes	No	Yes	Yes	Can't tell	No	Yes	No	Yes	Yes	Yes	No	No	Yes	Can't tell	Yes	No	Can't tell	Can't tell
Kim et al., 2019	Yes	Yes	No	Yes	Can't tell	Can't tell	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	Can't tell	Yes
Kosgeroglu et al., 2006	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Can't tell	Yes
Krstev et al., 2003	Yes	Yes	No	Yes	Yes	Can't tell	No	Yes	No	Yes	Can't tell	Yes	No	No	Yes	Yes	Can't tell	No	Can't tell	Can't tell
Kyprianou et al., 2010	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Can't tell	Can't tell	No	No	No	No	Yes	Yes	Can't tell	Can't tell
Lawson et al., 2019	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Can't tell	Not applicable	Yes	Yes	No	Not applicable	Yes	Yes	Yes	Yes	Can't tell	Yes
Lee et al., 2021	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Can't tell	Yes
Mahon et al., 1994	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Can't tell	Can't tell

Martin & Lawson, 2003	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	Can't tell
Menonna-Quinn et al., 2019	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	No	Can't tell
Momeni et al., 2013	Yes	Yes	No	Yes	Yes	Can't tell	No	Can't tell	No	Not applicable	No	No	Can't tell	No	Yes	Yes	Yes	No	No	Yes
Nieweg et al., 1994	Yes	Yes	No	Can't tell	Yes	Yes	No	Yes	No	Not applicable	Can't tell	Can't tell	No	No	Yes	Yes	Yes	No	Can't tell	Can't tell
Nwagbo et al., 2017	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Can't tell
Orujlu et al., 2016	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Can't tell	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	No	No	Yes
Pirot et al., 2023	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	No	Yes
Polovich & Clark, 2012	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Not applicable	Yes	Yes	Yes	Yes	No	Yes
Polovich & Martin, 2011	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	Yes	No	Can't tell
Rizalar et al., 2012	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Not applicable	Yes	No	Can't tell	No	No	Can't tell	No	No	Can't tell	Can't tell
Rogers, 1987	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Can't tell	No	Yes	No	Can't tell	Yes	Yes	Can't tell	No	Can't tell	Can't tell
Silver et al., 2016	Can't tell	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes
Srisintorn et al., 2021	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Can't tell	No	No	Yes	Yes	Yes	Yes	No	Yes
Stajich et al., 1986	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	Can't tell	Yes	Can't tell	No	Yes	Yes	Yes	Yes	Can't tell	Can't tell
Türk et al., 2004	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	No	No	Yes	No	Yes	No	No	Can't tell
Valanis & Browne, 1985	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	No	Not applicable	Yes	Can't tell	Can't tell	No	Yes	Yes	Yes	No	Can't tell	Can't tell
Valanis & Shortridge, 1987	Yes	Yes	No	Yes	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Can't tell	Can't tell
Valanis et al., 1991	Yes	Yes	Can't tell	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	Can't tell	No	Yes	Yes	Yes	Yes	Can't tell	Can't tell
Valanis et al., 1992	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Can't tell	Yes	No	Can't tell	Yes
Walton et al., 2020	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Can't tell	Yes	Can't tell	Yes	Can't tell	Yes
Zayed et al., 2019	Yes	Yes	No	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Yes	No	No	No	Not applicable	Yes	Can't tell	Can't tell	No	Can't tell	Yes
Cross-sectional and cohort studies – operating theatre setting																				
Benoist, Eveno, et al., 2022	Yes	Yes	No	Yes	Yes	Can't tell	No	Yes	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Yes	Yes	Yes	No	No	Yes
Clerc et al., 2021	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Can't tell	Yes	No	Yes	Can't tell	Yes

Can't tell: either not reported or insufficient information.

Table 4
Quality appraisal of qualitative studies using the critical appraisal skills programme (CASP).

Qualitative	1. Was there a clear statement of the aims of the research?	2. Is a qualitative methodology appropriate?	3. Was the research design appropriate to address the aims of the research?	4. Was the recruitment strategy appropriate to the aims of the research?	5. Was the data collected in a way that addressed the research issue?	6. Has the relationship between researcher and participants been adequately considered?	7. Have ethical issues been taken into consideration?	8. Was the data analysis sufficiently rigorous?	9. Is there a clear statement of findings?	10. How valuable is the research?
Batista et al., 2021	Yes	Yes	Yes	Yes	Yes	No	Can't tell	No	Yes	Yes
Chen et al., 2016	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes	Yes
Topcu & Beser, 2017	Yes	Yes	Can't tell	Can't tell	Yes	No	Yes	Yes	Yes	Yes

Can't tell: either not reported or insufficient information.

3.3.3. *Disposal*

Studies reported improper disposal practices, such as discarding hazardous drug contaminated waste with regular waste (Abbasi et al., 2016; Rogers, 1987; Rizalar et al., 2012) and, in older studies, pouring drugs down sinks (Goodman, 1985; Rogers, 1987; Valanis and Browne, 1985). Few studies reported on the use of personal protective equipment for disposal, and the use of incineration as the ideal way to dispose of hazardous drug contaminated waste was identified in one study (Asefa et al., 2021).

3.3.4. *Spill management and handling bodily fluids*

Two studies focused on spills, including nurses' experiences of what caused this increased risk of exposure and their practice for cleaning (Friese et al., 2020; He et al., 2017). The use of personal protective equipment when handling patients' bodily fluids (e.g., urine, stool, vomit) for at least 48 h after administration of a hazardous drug was reported in 14 studies (Table 2).

3.3.5. *Miscellaneous safe handling practices*

Studies investigated different aspects of recommended safe handling practices, including hand washing (Table 2), wrapping gauze around the top of an ampoule or intravenous connection (Kosgeroglu et al., 2006; Colvin et al., 2016), placing an absorbent pad under preparation equipment or injection sites (Ben-Ami et al., 2001; Boiano et al., 2014; Colvin et al., 2016; Kosgeroglu et al., 2006; Rizalar et al., 2012), using leur lock syringes (Asefa et al., 2021; Boiano et al., 2014; DeJoy et al., 2017; Silver et al., 2016), labelling drugs (Al-Azzam et al., 2015), and after 2014, adopting the use of Closed System drug-Transfer Devices (CSTDs), particularly in the United States (Table 2).

Hazardous drug handling practices that do not meet current guidelines were also reported and included the use of surgical masks (Elshaer, 2017; Chaudhary and Karn, 2012; Fuller et al., 2007; Mahon et al., 1994; Türk et al., 2004; Callahan et al., 2016; Boiano et al., 2014), reusable lab coats or cloth gowns (Valanis and Shortridge, 1987; Valanis and Browne, 1985; Martin and Larson, 2003; Mahon et al., 1994; Fuller et al., 2007; Polovich and Martin, 2011), re-using gloves (Boiano et al., 2014; Boiano et al., 2015), cleaning hands with alcohol hand rub (Friese et al., 2020), using horizontal flow cupboards (Valanis and Shortridge, 1987; Valanis and Browne, 1985; Momeni et al., 2013) and using personal protective equipment less often with crushed compared to intact tablets (Lawson et al., 2019).

Table 5
Quality appraisal of quantitative studies using the critical appraisal skills programme (CASP) randomised control trial standard.

Educational interventions	1. Did the study address a clearly focused research question?	2. Was the assignment of participants to interventions randomised?	3. Were all participants who entered the study accounted for at its conclusion?	4. Were the participants /investigators /analysts blind to the intervention?	5. Were the study groups similar at the start of the randomised controlled trial?	6. Apart from the experimental intervention, did each study group receive the same level of care?	7. Were the effects of intervention reported comprehensively?	8. Was the precision of the estimate of the intervention or treatment effect reported?	9. Do the benefits of the experimental intervention outweigh the harms and costs?	10. Can the results be applied to your local population/in your context?	11. Would the experimental intervention provide greater value than any of the existing interventions?
Crickman & Finnell, 2017	Yes	Not applicable	Yes	Not applicable	Not applicable	Not applicable	Yes	Yes	Yes	Yes	Can't tell
Friese et. al., 2019	Yes	Yes (by site)	No	No	Yes	Yes	Yes	Yes	No	No	No
Hojati et. al., 2023	Yes	Not applicable	Yes	Not applicable	Not applicable	Not applicable	Yes	Yes	Yes	Yes	Can't tell
Jun & Kang, 2023	Yes	Yes (by site)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Keat et. al., 2013	Yes	Not applicable	Yes	Not applicable	Not applicable	Not applicable	Yes	No	Yes	Yes	Can't tell
Nouri et. al., 2021	Yes	Not applicable	Yes	Not applicable	Not applicable	Not applicable	Yes	No	Yes	Yes	Yes

Can't tell: either not reported or insufficient information.

3.4. Attitudes or factors affecting knowledge and practice

The perception of risk in the operating room for hyperthermic intraperitoneal chemotherapy and pressurised intraperitoneal aerosol chemotherapy was reported in two studies. Hyperthermic intraperitoneal chemotherapy was considered to have a higher risk of exposure than pressurised intraperitoneal aerosol chemotherapy (Clerc et al., 2021; Benoist et al., 2022b).

Across the studies there was evidence of a moderately strong positive correlation between education and professional development, and glove use for the administration of hazardous drugs (marked with an * in Table 2). Cultural context, perceived time constraints, workload pressures, and scepticism about the necessity for precautions also influenced nurses' practices (Table 2). Some nurses believed their skills could prevent exposure, while others expressed concerns about the acute and long-term effects of hazardous drugs (Chen et al., 2016, Topcu and Beser, 2017). Nurses perceived that hospitals were concerned about the cost of safety and being non-compliant with personal protective equipment would reduce the hospital's expenses (Chen et al., 2016).

4. Discussion

This systematic review investigated what nurses and midwives know and do regarding their occupational exposure to hazardous drugs, and what factors affected their knowledge and practice. Two major gaps have been identified. First, there were no studies reporting what midwives know and do about their risk of occupational exposure to the hazardous drugs they handle, such as gentamicin, misoprostol and oxytocin. Second, the risk of occupational exposure to hazardous drugs outside of oncology services was rarely investigated.

4.1. What nurses know

The studies included in this review investigated nurses' knowledge of the potential health hazards posed by the medications they handle, focusing on a limited number of specialties. Although eight (13 %) studies used the term 'hazardous drugs', all but one (Fuller et al., 2007) investigated nurses working in oncology or handling cytotoxic (n = 10, 16 %), antineoplastic (n = 29, 47 %), chemotherapy (n = 14, 23 %) or anti-cancer drugs (n = 1, 2 %). This focus on oncology services means that little is known about nurses' and midwives' handling of hazardous drugs classified as non-cytotoxic or reproductively toxic.

Comparably, the policies and guidelines for handling hazardous drugs, which serve as an administrative control for risk management (Easty et al., 2015), do not always encompass the broader classification of hazardous drugs. In a recent systematic review of guidelines that were published after the 'NIOSH alert' (National Institute for Occupational Safety and Health, 2004), the 'type of substance' was referred to as hazardous drugs (n = 24, 39 %) or focused more specifically on antineoplastic agents (n = 27, 44 %) (Bernabeu-Martínez et al., 2018). This lack of a consistent broad emphasis in research, and polices and guidelines, could mean that many healthcare professionals are unaware of the full catalogue of medicines posing an exposure risk. For drugs that present reproductive or developmental hazards, it is important to consider managing the risk by having personnel change to a different clinical workplace when attempting conception, during pregnancy or while lactating, as well as ensuring the use of recommended personal protective equipment during these periods (ISOPP Standards Committee, 2022; National Institute for Occupational Safety and Health, 2023; Cancer Institute NSW, 2022). However, pregnancy may not always be planned or openly discussed, and all individuals at risk of exposure should be provided with and required to use personal protective equipment (National Institute for Occupational Safety and Health, 2023). It is the employer's responsibility to ensure that healthcare workers, including nurses and midwives, who handle hazardous drugs are aware of the potential for exposure, are informed of possible negative acute and chronic health effects, including adverse reproductive outcomes, and that a risk management plan is in place (National Institute for Occupational Safety and Health, 2023; ISOPP Standards Committee, 2022; SA Health, 2015). Policies and guidelines need to contain an up-to-date list of drugs that meet the hazardous classification, have comprehensive information about how exposure can occur, describe safe handling practices, be easily accessible and be read by both management and healthcare staff.

Furthermore, healthcare workers should receive training that covers the safe handling practices they can implement to mitigate exposure (Power and Coyne, 2018). In contrast to this recommendation, this review found that many nurses lacked formal undergraduate safe handling education, or initial and ongoing workplace training, with considerable variation across wards, hospitals, and countries. For example, in the United States there was a notable increase in the proportion of nurses trained over time, from 55 % in 1986 (Stajich et al.) to 96 % in 2020 (Walton et al.), potentially due to the 'NIOSH alert', the availability of guidance documents and the enforceable United States Pharmacopeia convention <800> standard (Polovich and Olsen, 2018; United States Pharmacopeia, 2020; National Institute for Occupational Safety and Health, 2004; Bernabeu-Martínez et al., 2018). However, this increase in the proportion of trained nurses was not the case in all countries. Three studies, reporting on practices from different provinces in Iran, were published within a two-year period. One study reported 64 % of nurses had received training, the second reported that 74 % were oncology trained and 44 % had had ongoing training, while in the third study only 9 % of nurses had undertaken a short course (Abbasi et al., 2016; Alehashem and Baniasadi, 2018; Orujlu et al., 2016). The inconsistent

provision of training for nurses may have stemmed from the onus being placed on employers to provide workplace specific training, coupled with the varying resources available across different healthcare settings at that time.

Limited studies reported on undergraduate training, with contrasting findings; Keat et al. (2013) found nurses received no pre-registration education on handling cytotoxic drugs, while Jeong et al. (2015) reported 61 % received safety education in nursing school. Notably in the wider literature, a German study demonstrated that additional teaching on hazardous drug handling improved nursing students' knowledge, practical skills, and reduced work surface contamination compared to routine pre-registration education (Zimmer et al., 2017). This suggests that improved handling practices learned during training can translate to reduced risks and adverse health effects in future clinical practice. To adequately prepare nurses, and by extension, midwives, safe handling education should begin in undergraduate courses and be followed by continuous education and training provided by the employer from the start of employment, even in resource limited healthcare settings (Abu-Alhaija et al., 2023, ISOPP Standards Committee, 2022, Power and Coyne, 2018, Pan American Health Organization, 2013).

4.2. What nurses do

This systematic review included the drug handling activities that nurses and midwives undertake in their everyday work practice. These different handling activities: preparation, administration, disposal, spill management and handling bodily fluids, have all previously been classified as activities where there is a risk of exposure (Bernabeu-Martínez et al., 2018). Despite historic (Hoffman, 1980; Davis, 1981) and current guidelines (Bernabeu-Martínez et al., 2018) recommending that hazardous drugs be prepared in a central location by pharmacists, the findings from this review indicate that preparation by nurses was common. Only four studies reported pharmacists were solely responsible for preparation (Srisintorn et al., 2021; Graeve et al., 2017; Chen et al., 2016; Colvin et al., 2016), and one study reported on an intervention which included the initiation of cytotoxic drug preparation services by pharmacists (Keat et al., 2013). The availability and use of biological safety cabinets, a critical engineering control for preparing hazardous drugs, varied widely across studies when nurses prepared these medications (Table 2). This inconsistent adherence to the use of recommended engineering controls is concerning, as it increases nurses' risk of occupational exposure. These findings highlight two crucial needs: first, stricter implementation of guidelines by nurses for safe handling practices; second improved access to appropriate facilities and equipment provided by employers to ensure safe preparation practices (Kibby, 2017; Crickman and Finnell, 2016). This is particularly important if nurses continue to have the clinical responsibility for preparing hazardous drugs.

Closed system drug-transfer devices are supplemental engineering controls designed to mechanically inhibit the escape of hazardous drug residues and aerosols into the environment (Erce, 2015). The use of closed system drug-transfer devices was reported in the studies in this review from 2014 onwards, likely due to the United States Pharmacopeia convention <800> standard requiring the use of closed system drug-transfer devices for the administration of antineoplastic hazardous drugs, where dosage forms allow (United States Pharmacopeia, 2020). However, while closed system drug-transfer devices may reduce the hazardous drug contamination of the healthcare environment, they do not eliminate it entirely (Power, 2013; Besheer et al., 2020). A Cochrane systematic review comparing closed system drug-transfer devices plus safe handling practices to safe handling alone, primarily involving pharmacists and pharmacy technicians, found insufficient evidence to clearly support closed system drug-transfer device use in clinical practice (Gurusamy et al., 2018). The review suggested future studies should include patient care areas and nurses (Gurusamy et al., 2018). Notably, in Friese et al.'s (2020) study, 41 out of 51 participants reported using closed system drug-transfer devices, but 21 of those participants indicated the devices did not function properly during hazardous drug spills (Friese et al., 2020). These findings underscore the importance of proper closed system drug-transfer device training and use, if they are to be used by nurses and midwives, to ensure secure connections and effective operation (Nurgat et al., 2019).

The use of personal protective equipment is the most common but least effective control for the management of risk associated with exposure to hazardous drugs (National Institute for Occupational Safety and Health, 2022). In studies comparing self-reported practices with observed behaviours, there was a negative association between what nurses knew they should do and what they actually did in practice (Colvin et al., 2016; Kosgeroglu et al., 2006). The availability of safety equipment did not correlate with its universal adoption by nurses, despite the studied populations of nurses almost exclusively working in oncology, where occupational exposure risks and safe handling guidelines have been known for over forty years (Davis, 1981; Bernabeu-Martínez et al., 2018; National Institute for Occupational Safety and Health, 2004). This incongruency between guidelines and appropriate personal protective equipment use is not unique to nursing but also occurs in manufacturing, farming and construction workplaces (Geer et al., 2007; McCullagh et al., 2002; Zhao et al., 2015).

The need to use personal protective equipment has been shown to be essential, because even when nurses do use safe handling practices, surface contamination studies in cancer centres report ongoing measurable levels of antineoplastic drug contamination in preparation and administration areas, even when biological safety cabinets and closed system drug-transfer devices were used (Connor et al., 1999; Chabut et al., 2021). The total amount of surface contamination in healthcare settings is difficult to quantify. Testing can be used to indicate the presence of surface contamination, however the results reported in studies were only quantifiable for the selected marker drugs, which were commonly administered cytotoxic drugs such as cyclophosphamide or fluorouracil (Muller-Ramirez et al., 2017; Doležalová et al., 2022; Chabut et al., 2022). Monitoring programs for surface contamination in healthcare settings can be used to identify the specific locations of contamination, which can consequently indicate where there are potential problems with both safe handling practices and cleaning by housekeeping, and when monitoring is repeated, changes in contamination over time can be assessed.

4.3. Attitudes or factors affecting knowledge and practice

In this review, a moderately strong correlation was found between training and nurses' use of some personal protective equipment. The Health Promotion Model, which explains the multidimensional factors influencing individual nurses' attitudes and behaviours (Pender et al., 2015), was the most cited framework for understanding nurses' personal protective equipment use (Table 2). Nurses attributed their personal protective equipment use to cultural context, perceived benefits and barriers, self-efficacy, and interpersonal and situational influences (Table 2). While historical and cultural changes have increased education and personal protection equipment use, as the hazards of hazardous drugs were recognised and risk management controls evolved, safe-handling precautions have not been universally adopted by oncology nurses (Polovich and Clark, 2012). This contrasts starkly with the behaviour modifications seen in the universal adoption of standard precautions for infection prevention and control following the awareness of the occupational health hazard related to bloodborne human immunodeficiency virus in the 1980s (Weber et al., 2020). The difference in motivation may stem from the latent period between exposure and disease onset or the difficulty in directly linking health and reproductive outcomes to hazardous drug exposure. Although evidence-based guidelines recommend safe handling practices, their actual implementation in everyday patient care is crucial and needs to be improved to reduce exposure risks. A strong workplace safety climate, where

employers prioritise hazardous drug related safety, is a key predictor for adopting risk management controls (Polovich, 2020). Organisational dimensions, such as management support, minimising barriers, maintaining a clean and uncluttered work area, effective communication, staff cooperation, providing training and feedback, and ensuring the availability of controls, are essential for supporting safe handling practices (McDiarmid and Condon, 2005; Polovich, 2020).

4.4. Implications for nursing and midwifery practice

The findings of this review have significant implications for nursing and midwifery practice. As mentioned, hazardous drugs are not limited to antineoplastics used in oncology but encompass a diverse array of therapeutic classes utilised for various medical conditions across different healthcare specialties (Lindsley and Musu, 2022). Consequently, the preventative measures and safe handling practices discussed in this review are applicable to all healthcare areas where nurses and midwives administer medications.

To reduce the potential for occupational exposure, elimination and substitution controls are the most effective. One example is prescribing different dosage forms as part of the treatment protocol, such as tablets instead of intravenous infusions, when these are available and appropriate for the patient. Tablets can be self-administered by patients, washing their hands with soap and water afterwards (International Society of Oncology Pharmacy Practitioners Standards Committee, 2022; Hassan et al., 2023). Although there is still potential for exposure, it is considered less with intact tablets compared to intravenous infusions (Victorian Therapeutics Advisory Group, 2021; Nguyen et al., 2024).

Administrative controls, such as educating nurses and midwives about potential exposure and safe handling practices, maintaining up-to-date site-specific hazardous drug lists, regularly reviewing guidelines and policies, and having pharmacy professionals both prepare hazardous drugs in an environment with engineering controls and prime intravenous tubing with non-drug compatible fluid, can reduce exposure risks for nurses and midwives (Easty et al., 2015; National Institute for Occupational Safety and Health, 2023). Other administrative controls include providing conveniently located hazardous drug waste containers and spill kits, and labelling medicines as hazardous with physical labels and with warning messages within electronic medication records (Gruenewald and Gilkey, 2021; Easty et al., 2015).

To minimise potential hazardous drug contamination while using personal protective equipment, nurses and midwives should remove their outer layer of double gloves before touching the intravenous infusion pump or work environment, remove all their personal protective equipment before leaving the work area and wash their hands immediately after doffing personal protective equipment (National Institute for Occupational Safety and Health, 2023; Boiano et al., 2014). Furthermore, healthcare staff should use disposable wipes to clean surfaces and floors that may be contaminated, and dispose of these wipes and the personal protective equipment used as hazardous drug waste (Polovich, 2020).

4.5. Future research

Future studies are required to investigate the occupational exposure risk of nurses and midwives in all areas of healthcare where hazardous drugs are administered. The data collected can then inform educational strategies to reduce occupational exposure to all hazardous drugs. It is possible it will be found that the COVID-19 pandemic has had a positive impact on personal protective equipment use. There may be an increased availability of personal protective equipment in previously underserved healthcare areas, and access to more suitable personal protective equipment for handling hazardous drugs, such as N95 masks. Also, cleaning practices by nurses, midwives and other healthcare staff may be more extensive.

During the pandemic, the widespread use of personal protective equipment may have addressed some potential perceived barriers. For instance, nurses and midwives wearing 'full' personal protective equipment may no longer perceive this as a barrier to building relationships with patients. Additionally, they may have received training about proper donning and doffing techniques, and disposal to avoid self-contamination, increasing their self-efficacy for using personal protective equipment (Ha, 2020).

Constraints on research design in terms of time and resources meant that most of the studies utilised self-administered or interviewer-completed questionnaires and therefore included data that were self-reported by nurses. This introduced the potential for response bias, as nurses may have answered in a way that they perceived to be socially acceptable, and relied on their recollection of safe handling practices, which can be subject to recall bias. Along with this methodological limitation, the common use of convenience sample recruitment strategies means that the data may not be truly representative of the population studied. Ideally researchers of future studies will use randomised recruitment methods with optimal sample sizes.

4.6. Limitations

A key characteristic of this systematic review is the heterogeneity of the instruments used across the included studies, as well as the varying and often incomplete aspects of hazardous drug safe handling practices reported. While some studies focused on overall hazardous drug handling, others investigated more specific aspects of handling. Additionally, the studies primarily reported on the use of personal protective equipment, with different types of equipment being worn, such as aprons and gowns, and in some cases, inappropriate protective equipment like surgical masks and laboratory coats. The inconsistency in personal protective equipment usage further contributes to the difficulty in drawing comprehensive comparisons and conclusions from the available data.

The concentration of approximately half the studies being from the geographical area of North America may limit the applicability of the findings to low-income countries and the data from oncology settings may not apply to the broader nursing and midwifery population. Furthermore, in the risk of bias assessments, it was found that very few researchers had calculated a sample size, thus limiting the interpretation of the findings. Without ensuring adequate sample size, it cannot be certain there was sufficient statistical power to draw reliable conclusions from the data.

The prospective registration of the systematic review protocol and the use of software to blind the duplicate data extraction, with a third person completing the consensus process, has been used to minimise selection bias.

5. Conclusion

This review investigated studies on the risk of exposure to hazardous drugs, primarily classified as cytotoxic or antineoplastic. The findings revealed that nurses working in oncology settings were mainly responsible for preparing these drugs, rather than pharmacists, and often lacked understanding of occupational exposure risks. Furthermore, while no studies assessed midwives' knowledge and safe handling practices, only one focused on nurses handling a broader definition of hazardous drugs beyond oncology use. Key contributing factors to nurses' non-adherence to evidence-based guidelines included perceived low risk, lack of personal protective equipment availability, and prioritising personal or patient comfort over safety measures.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnurstu.2024.104907.

Funding

This research was supported by an Australian Government Research

Training Program (RTP) Scholarship.

CRediT authorship contribution statement

Pheona van Huizen: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Philip L. Russo:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Elizabeth Manias:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Lisa Kuhn:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Clifford J. Connell:** Writing – review & editing, Supervision, Data curation, Conceptualization.

Declaration of Competing Interest

None.

References

Abbasi, K., Hazrati, M., Mohammadbeigi, A., Ansari, J., Sajadi, M., Hosseinnazzhad, A., Moshiri, E., 2016. Protection behaviors for cytotoxic drugs in oncology nurses of chemotherapy centers in shiraz hospitals, south of Iran. Indian Journal of Medical and Paediatric Oncology 37, 227–231.

Abu Sharour, L., Subih, M., Bani Salameh, A., Malak, M., 2021. Predictors of chemotherapy safe-handling precautions and knowledge among a sample of Jordanian oncology nurses: A model-building approach. Workplace Health and Safety 69, 115–123.

Abu-Alhaija, D., Bakas, T., Shaughnessy, E., Miller, E., 2023. The Factors that Influence Chemotherapy Exposure among Nurses: An Integrative Review. Workplace Health & Safety.

Al Hosni, M., Rouget, C., Cusumano, C., Garcia Lozcano, E., Popescu, H., Carrere, S., Quénet, F., Sgarbura, O., 2020. Non-medical caregivers and the use of intraperitoneal chemotherapy in the operating theatre: a survey on the perception of safety. J. Visc. Surg. 157, 461–467.

Al-Azzam, S., Awawdeh, B., Alzoubi, K., Khader, Y., Alkafajei, A., 2015. Compliance with safe handling guidelines of antineoplastic drugs in Jordanian hospitals. J. Oncol. Pharm. Pract. 21, 3–9.

Alehashem, M., Baniasadi, S., 2018. Safe handling of anti-neoplastic drugs in the university hospitals: A descriptive survey study among oncology nurses. International Journal of Cancer Management 11, e6482.

Asefa, S., Aga, F., Dinegde, N., Demie, T., 2021. Knowledge and practices on the safe handling of cytotoxic drugs among oncology nurses working at tertiary teaching hospitals in Addis Ababa, Ethiopia. Drug, Healthcare and Patient Safety 13, 71–80.

Banihani, S., Habashneh, S., Suhemat, A., Awabdeh, E., Alshraideh, J., 2022. Effects of educational interventions to improve safe hazardous drug handling among oncology nurses: systematic review. Medico-legal Update 22, 97–105.

Batista, K., Sousa, K., Ruas, C., Zeitoune, R., 2021. Knowledge about antineoplastic drugs: implications for the health of nursing workers in a general hospital. Rev. Bras. Enferm. 75 (e20210025), 1–9.

Baykal, U., Seren, S., Sokmen, S., 2009. A description of oncology nurses' working conditions in Turkey. Eur. J. Oncol. Nurs. 13, 368–375.

Ben-Ami, S., Shaham, J., Rabin, S., Melzer, A., Ribak, J., 2001. The influence of nurses' knowledge, attitudes, and health beliefs on their safe behavior with cytotoxic drugs in Israel. Cancer Nurs. 24, 192–200.

Benoist, H., Busson, A., Faveyrial, A., Bouhier-Leporrier, K., Divanon, F., Breuil, C., Roger-Leenaert, S., Palix, A., Odou, P., Simon, N., Saint-Lorant, G., 2022a. Perception, knowledge, and handling practice regarding the risk of exposure to antineoplastic drugs in oncology day hospitalization units and compounding unit staff. J. Oncol. Pharm. Pract. 1–11.

Benoist, H., Eveno, C., Wilson, S., Vigneron, N., Guilloit, J., Morello, R., Simon, N., Odou, P., Saint-Lorant, G., 2022b. Perception, knowledge and protective practices for surgical staff handling antineoplastic drugs during HIPEC and PIPAC. Pleura and Peritoneum 7, 77–86.

Bernabeu-Martínez, M.A., Ramos Merino, M., Santos Gago, J.M., Álvarez Sabucedo, L.M., Wanden-Berghe, C., Sanz-Valero, J., 2018. Guidelines for safe handling of hazardous drugs: A systematic review. PloS One 13, e0197172.

Besheer, A., Mahler, H., Matter-Schwald, A., Barrenechea, S., Vogt, M., Chalus, P., Heymes, P., Pillow, T., Kirste, A., Favrod, P., Joerg, S., Mathaes, R., 2020. Evaluation of different quality-relevant aspects of closed system transfer devices (CSTDs). Pharm. Res. 37 (81), 1–12.

Boiano, J., Steege, A., Sweeney, M., 2014. Adherence to safe handling guidelines by health care workers who administer antineoplastic drugs. J. Occup. Environ. Hyg. 11, 728–740.

Boiano, J., Steege, A., Sweeney, M., 2015. Adherence to precautionary guidelines for compounding antineoplastic drugs: A survey of nurses and pharmacy practitioners. J. Occup. Environ. Hyg. 12, 588–602.

Brink, F., 2016. Safe Handling of Antineoplastic Drugs at a Public Hospital in Guangzhou, China: An Observational Study in Clinical Practice. Sophiahemmet University College.

Broto, M., Galve, R., Marco, M., 2017. Bioanalytical methods for cytostatic therapeutic drug monitoring and occupational exposure assessment. Trends Anal. Chem. 93, 152–170.

Callahan, A., Ames, N., Manning, M., Touchton-Leonard, K., Yang, L., Wallen, G., 2016. Factors influencing nurses' use of hazardous drug safe-handling precautions. Oncol. Nurs. Forum 43, 343–349.

Cancer Institute NSW. 2022. *Safe handling and waste management of hazardous drugs. ID: 188 v9* [Online]. https://www.eviq.org.au/clinical-resources/administration-of-anti-cancer-drugs/188-safe-handling-and-waste-management-of-hazardou#safe-handling-of-reproductive-hazardous-drugs: NSW government. [Accessed 27th February 2024].

Cancer Institute NSW. 2024. *Hazardous drugs table. ID: 909 v9* [Online]. https://www.eviq.org.au/clinical-resources/administration-of-anti-cancer-drugs/909-hazardous-drugs-table#: NSW government. [Accessed 27th February 2024].

Chabut, C., Tanguay, C., Gagné, S., Caron, N., Bussières, J.-F., 2021. Surface contamination with nine antineoplastic drugs in 109 Canadian centers; 10 years of a monitoring program. J. Oncol. Pharm. Pract. 107815522199210.

Chabut, C., Tanguay, C., Gagne, S., Caron, N., Bussieres, J., 2022. Surface contamination with nine antineoplastic drugs in 109 Canadian centers; 10 years of a monitoring program.Pdf. J. Oncol. Pharm. Pract. 28, 343–352.

Chaudhary, R., Karn, B., 2012. Chemotherapy-knowledge and handling practice of nurses working in a medical university of Nepal. J. Cancer Ther. 3, 110–114.

Chen, H.C., Lu, Z.Y.J., Lee, S.H., 2016. Nurses' experiences in safe handling of chemotherapeutic agents: the Taiwan case. Cancer Nurs. 39, E29–E38.

Choi, J., Kim, Y., Gong, S., 2004. Level of knowledge and compliance on guidelines for safe handling of cytotoxic drugs by career and work units in clinical nurses. Journal of Korean Clinical Nursing Research 9, 6–17.

Clerc, D., Hübner, M., Ashwin, K., Somashekhar, S., Rau, B., Ceelen, W., Willaert, W., Bakrin, N., Laplace, N., Al Hosni, M., Garcia Lozcano, E., Blaj, S., Piso, P., Di Giorgio, A., Vizzelli, G., Brigand, C., Delhorme, J., Klipfel, A., Archid, R., Nadiradze, G., Reymond, M., Sgarbura, O., 2021. Current practice and perceptions of safety protocols for the use of intraperitoneal chemotherapy in the operating room: results of the IP-OR international survey. Pleura and Peritoneum 6, 39–45.

Colvin, C., Karius, D., Albert, N., 2016. Nurse adherence to safe-handling practices: observation versus self-assessment. Clin. J. Oncol. Nurs. 20, 617–622.

Connor, T., Anderson, R., Sessink, P., Broadfield, L., Power, L., 1999. Surface contamination with antineoplastic agents in six cancer treatment centers in the United States and Canada. Am. J. Health-Syst. Pharm. 56, 1427–1432.

Connor, T., Debord, D., Pretty, J., Oliver, M., Roth, T., Lees, P., Krieg, E., Rogers, B., Escalante, C., Toennis, C., Clark, J., Johnson, B., Mcdiarmid, M., 2010. Evaluation of antineoplastic drug exposure of health care workers at three university-based US cancer centers. J. Occup. Environ. Med. 52, 1019–1027.

Coyne, E., Northfield, S., Ash, K., Brown-West, L., 2019. Current evidence of education and safety requirements for the nursing administration of chemotherapy: an integrative review. Eur. J. Oncol. Nurs. 41, 24–32.

Crickman, R., Finnell, D., 2016. Systematic review of control measures to reduce hazardous drug exposure for health care workers. J. Nurs. Care Qual. 31, 183–190.

Crickman, R., Finnell, D., 2017. Chemotherapy safe handling. Limiting nursing exposure with a hazardous drug control program. Clin. J. Oncol. Nurs. 21, 73–78.

Critical Appraisal Skills Programme. 2021a. *CASP qualitative studies checklist* [Online]. Available: https://casp-uk.net/casp-tools-checklists/ [Accessed 28th January 2024].

Critical Appraisal Skills Programme. 2021b. *CASP randomised control trial checklist* [Online]. Available: https://casp-uk.net/casp-tools-checklists/ [Accessed 28th January 2024].

Crudi, C., Stephens, B., Maier, P., 1982. Possible occupational hazards associated with the preparation, administration of antineoplastic agents. NITA (Journal of the National Intravenous Therapy Association) 5, 264–266.

Davis, M., 1981. Guidelines for safe handling of cytotoxic drugs in pharmacy departments and hospital wards. Hosp. Pharm. 16, 17–20.

DeJoy, D., Smith, T., Woldu, H., Dyal, M., Steege, A., Boiano, J., 2017. Effects of organizational safety practices and perceived safety climate on PPE usage, engineering controls, and adverse events involving liquid antineoplastic drugs among nurses. J. Occup. Environ. Hyg. 14, 485–493.

Doležalová, L., Bláhová, L., Kuta, J., Hojdarová, T., Kozáková, Š., Bláha, L., 2022. Levels and risks of surface contamination by thirteen antineoplastic drugs in the Czech and Slovak hospitals and pharmacies. Environ. Sci. Pollut. Res. 29, 26810–26819.

Downes, M., Brennan, M., Williams, H., Dean, R., 2016. Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). BMJ Open 6.

Dranitsaris, G., Johnson, M., Poirier, S., Schueller, T., Milliken, D., Green, E., Zanke, B., 2005. Are health care providers who work with cancer drugs at an increased risk for toxic events? A systematic review and meta-analysis of the literature. J. Oncol. Pharm. Pract. 11, 69–78.

Dunne, C., 1989. Safe handling of antineoplastic agents-self-learning module. Cancer Nurs. 2, 120–127.

Easty, A., Coakley, N., Cheng, R., Cividino, M., Savage, P., Tozer, R., White, R., 2015. Safe handling of cytotoxics: guideline recommendations. Curr. Oncol. 22, e27–e37.

Eisenberg, S., Klein, C., 2021. Safe handling of hazardous drugs in home infusion. J. Infus. Nurs. 44, 137–146.

Elshaer, N., 2017. Adverse health effects among nurses and clinical pharmacists handling antineoplastic drugs: adherence to exposure control methods. J. Egypt. Public Health Assoc. 92, 144–155.

Erce, A. (Ed.), 2015. Preventing Occupational Exposure to Cytotoxic and Other Hazardous Drugs: European Policy Recommendations. European Parliament.

Fazel, S.S., Keefe, A., Shareef, A., Palmer, A.L., Brenner, D.R., Nakashima, L., Koehoorn, M.W., Mcleod, C.B., Hall, A.L., Peters, C.E., 2022. Barriers and facilitators for the safe handling of antineoplastic drugs. J. Oncol. Pharm. Pract. 28, 1709–1721.

Ferguson, S., Kerrigan, M., Hovey, K., 2020. Leveraging the opportunities of mixed methods in research synthesis: key decisions in systematic mixed studies review methodology. Res. Synth. Methods 11, 580–593.
Forough, A., Lau, E., Steadman, K., Kyle, G., Cichero, J., Serrano Santos, J., 2020. Appropriateness of oral dosage form modification for aged care residents: a video-recorded observational study. Int. J. Clin. Pharm. 42, 938–947.
Friese, C., 2012. Practice environments of nurses employed in ambulatory oncology settings: measure refinement. Oncol. Nurs. Forum 39, 166–172.
Friese, C., Yang, J., Mendelsohn-Victor, K., Mccullagh, M., 2019. Randomized controlled trial of an intervention to improve nurses' hazardous drug handling. Oncol. Nurs. Forum 46, 248–256.
Friese, C., Wong, M., Fauer, A., Mendelsohn-Victor, K., Polovich, M., Mccullagh, M., 2020. Hazardous drug exposure: case report analysis from a prospective, multisite study of oncology nurses' exposure in ambulatory settings. Clin. J. Oncol. Nurs. 24, 249–255.
Fuller, T., Bain, E., Sperrazza, K., Mazzuckeilli, L., 2007. A survey of the status of hazardous drug awareness and control in a sample Massachusetts nursing population. J. Occup. Environ. Hyg. 4, D113–D119.
Gallant C (Co-ordinator) 2008. *Prevention Guide. Safe Handling of Hazardous Drugs,* Montreal, Canada, Association paritaire pour la santé et la sécurité du travail du secteur affaires sociales [ASSTSAS].
Gaskins, A., Rich-Edwards, J., Lawson, C., Schernhammer, E., Missmer, S., Chavarro, J., 2015. Work schedule and physical factors in relation to fecundity in nurses. Occup. Environ. Med. 72, 777–783.
Geer, L., Curbow, B., Anna, D., Lees, P., Buckley, T., 2006. Development of a questionnaire to assess worker knowledge, attitudes and perceptions underlying dermal exposure. Scand. J. Work Environ. Health 32, 209–218.
Geer, L., Anna, D., Curbow, B., Diener-West, M., Van Wendel De Joode, B., Mitchell, C., 2007. Survey assessment of worker dermal exposure and underlying behavioral determinants. J. Occup. Environ. Hyg. 4, 809–820.
Gershon, R., Vlahov, D., Felknor, S., Vesley, D., Johnson, P., Delclos, G., Murphy, L., 1995. Compliance with universal precautions among health care workers at three regional hospitals. Am. J. Infect. Control 23, 225–236.
Gershon, R., Karkashian, C., Grosch, J., Murphy, L., Escamilla-Cejudo, A., Flanagan, P., Bernacki, E., Kasting, C., Martin, L., 2000. Hospital safety climate and it's relationship witth safe work practices and workplace exposure incidents. Am. J. Infect. Control 28, 211–221.
Gershon, R., Qureshi, K., Pogorzelska, B., Rosen, J., Gebbie, K., Brandt-Rauf, P., Sherman, M., 2007. Non-hospital based registered nurses and the risk of bloodborne pathogen exposure. Ind. Health 45 (5), 695. https://doi.org/10.2486/indhealth.45.695.
Goodman, C., 1985. Cytotoxic drugs: their handling and use. Nurs. Times 81, 36–38.
Graeve, C., Mcgovern, P., Alexander, B., Church, T., Ryan, A., Polovich, M., 2017. Occupational exposure to antineoplastic agents. Workplace Health & Safety 65, 9–20.
Gruenewald, B., Gilkey, D., 2021. Hazardous drug exposure in healthcare. World Safety Journal 30, 72–76.
Gurusamy, K.S., Best, L.M., Tanguay, C., Lennan, E., Korva, M., Bussières, J.-F., 2018. Closed-system drug-transfer devices plus safe handling of hazardous drugs versus safe handling alone for reducing exposure to infusional hazardous drugs in healthcare staff. Cochrane Database Syst. Rev. 1–127. Issue 3. Art. No.: CD012860.
Ha, J., 2020. The COVID-19 pandemic, personal protective equipment and respirator: A narrative review. Int. J. Clin. Pract. 74, e13578.
Hassan, M.M., Al-Marzooq, D., Al-Habsi, H., Al-Hashar, A., Al-Khabori, M., Al-Moundhri, M., Al-Zakwani, I., 2023. Patients' knowledge and awareness of safe handling of oral anticancer agents at Sultan Qaboos University Hospital in Oman. J. Oncol. Pharm. Pract. 29, 112–118.
Hazrati, M., Torabizade, K., Reisi, H., Pasyar, N., 2008. The effect of educating standard instructions on administration of antineoplastic drugs in chemotherapy centers in Shiraz. Hormozgan Medical Journal 12 (2), 104–109.
He, B., Mendelsohn-Victor, K., Mccullagh, M., Friese, C., 2017. Personal protective equipment use and hazardous drug spills among ambulatory oncology nurses. Oncol. Nurs. Forum 44, 60–65.
Hoffman, D., 1980. The handling of antineoplastic drugs in a major cancer center. Hosp. Pharm. 15, 302–304.
Hojati, Z., Goudarzi, F., Hasanvand, S., Galehdar, N., Birjandi, M., 2023. The impact of training chemotherapy safety standards with a smartphone application on the knowledge, attitude, and performance of nurses. BMC Nurs. 22, 1–11.
Hon, C., Barzan, C., Astrakianakis, G., 2014. Identification of knowledge gaps regarding healthcare workers' exposure to antineoplastic drugs: review of literature, North America versus Europe. Saf. Health Work 5, 169–174.
Hon, C., Teschke, K., Shen, H., 2015. Health care workers' knowledge, perceptions, and behaviors regarding antineoplastic drugs: survey from British Columbia, Canada. J. Occup. Environ. Hyg. 12, 669–677.
International Society of Oncology Pharmacy Practitioners Standards Committee, 2022. ISOPP standards for the safe handling of cytotoxics. J. Oncol. Pharm. Pract. 28, S1–S126.
Jeong, K., Lee, B., Kwon, M., Jang, J., 2015. Safety management status among nurses handling anticancer drugs: nurse awareness and performance following safety regulations. Asian Pac. J. Cancer Prev. 16, 3203–3211.
Jun, E., Kang, S., 2023. Effects of safe handling education on cognition, compliance and stress handling of antineoplastic drugs in clinical nurses. Nurs. Open 10, 4144–4152.
Jung, J., Park, J., 2019. Factors influencing compliance with safety guidelines of anticancer drugs among nurses in general hospitals. Asian Oncol. Nurs. 19, 106–113.
Karadakovan, A., 1999. The investigation of protective nursing precautions taken in chemotherapy applications. J. BUON 4, 311–315.
Keat, C., Sooaid, N., Yun, C., Sriraman, M., 2013. Improving safety-related knowledge, attitude and practices of nurses handling cytotoxic anticancer drug: Pharmacists' experience in a general hospital, Malaysia. Asian Pac. J. Cancer Prev. 14, 69–73.
Ko, H., 2017. The Relationship of Antineoplastic Agents Safety Management Guidelines Knowledge, Implementation and Anxiety Due to Exposure. Kosin Univ., Busan [master's thesis].
Kibby, T., 2017. A review of surface wipe sampling compared to biologic monitoring for occupational exposure to antineoplastic drugs. J. Occup. Environ. Hyg. 14, 159–174.
Kim, B., 1996. Urinary mutagenicity, physical symptoms and stress of nurses handling anticancer drugs. Journal of Nurses Academic Society 26, 963–975.
Kim, O., Lee, H., Jung, H., Jang, H., Pang, Y., Cheong, H., 2019. Korean nurses' adherence to safety guidelines for chemotherapy administration. Eur. J. Oncol. Nurs. 40, 98–103.
Korean Oncology Nursing Society, 2008. Safe handling guideline of cytotoxic drugs: chemotherapy. Journal of Korean Oncology Nursing 8, 178–190.
Kosgeroglu, N., Ayranci, U., Ozerdogan, N., Demirustu, C., 2006. Turkish nurses' information about, and administration of, chemotherapeutic drugs. J. Clin. Nurs. 15, 1179–1187.
Krstev, S., Perunicic, B., Vidakovic, A., 2003. Work practice and some adverse health effects in nurses handling antineoplastic drugs. Med. Lav. 94, 432–439.
Kyprianou, M., Kapsou, M., Raftopoulos, V., Soteriades, E., 2010. Knowledge, attitudes and beliefs of Cypriot nurses on the handling of antineoplastic agents. Eur. J. Oncol. Nurs. 14, 278–282.
Lawson, C., Johnson, C., Nassan, F., Connor, T., Boiano, J., Rocheleau, C., Chavarro, J., Rich-Edwards, J., 2019. Antineoplastic drug administration by pregnant and nonpregnant nurses: an exploration of the use of protective gloves and gowns. Am. J. Nurs. 119, 28–35.
Lee, S., Tkaczuk, M., Jankewicz, G., Ambados, F., 2007. Surface contamination from cytotoxic chemotherapy following preparation and administration. J. Pharm. Pract. Res. 37, 271–276.
Lee, H., Song, J., Ahn, J., Boo, S., 2021. Factors influencing compliance with safe handling of antineoplastic agents among clinical nurses. Asian Oncology Nursing 21, 42–51.
Leso, V., Sottani, C., Santocono, C., Russo, F., Grignani, E., Iavicoli, I., 2022. Exposure to antineoplastic drugs in occupational settings: A systematic review of biological monitoring data. Int. J. Environ. Res. Public Health 19, 3737.
Lindsley, I., Musu, T., 2022. The ETUI's List of Hazardous Medicinal Products (HMPs) Including Cytotoxics and Based on the EU CLP Classification System of Carcinogenic, Mutagenic and Reprotoxic (CMR) Substances. Europe/Brussels, The European Trade Union Institute.
Lockwood, C., Munn, Z., Porritt, K., 2015. Qualitative research synthesis: methodological guidance for systematic reviewers utilizing meta-aggregation. Int. J. Evid. Based Healthc. 13, 179–187.
Mahon, S., Casperson, D., Yackzan, S., Goodner, S., Hasse, B., Hawkins, J., Parham, J., Rimkus, C., Schlomer, M., Witcher, V., 1994. Safe handling practices of cytotoxic drugs: the results of a chapter survey. Oncol. Nurs. Forum 21, 1157–1165.
Martin, S., Larson, E., 2003. Chemotherapy-handling practices of outpatient and office-based oncology nurses. Oncol. Nurs. Forum 30, 575–581.
Marx, A., Nowicki, D., Carlson, R., Schultz, K., Sickbert-Bennett, E., Weber, D., 2023. Bacille Calmette-Guérin preparation and intravesical administration to patients with bladder cancer: risks to healthcare personnel and patients, and mitigation strategies. Infect. Control Hosp. Epidemiol. 1–6.
McCullagh, M., Lusk, S., Ronis, D., 2002. Factors influencing use of hearing protection among farmers. Nurs. Res. 51, 33–39.
McDiarmid, M.A., Condon, M., 2005. Organizational safety culture/climate and worker compliance with hazardous drug guidelines: lessons from the blood-borne pathogen experience. J. Occup. Environ. Med. 47, 740–749.
Menonna-Quinn, D., Polovich, M., Marshall, B., 2019. Personal protective equipment: evaluating usage among inpatient and outpatient oncology nurses. Clin. J. Oncol. Nurs. 23, 260–265.
Momeni, M., Danaei, M., Askarian, M., 2013. How do nurses manage their occupational exposure to cytotoxic drugs? A descriptive survey in chemotherapy settings, shiraz. Iran. International Journal of Occupational & Environmental Medicine 4, 102–106.
Morris, G., Cannady, R., 2019. Proper use of the hierarchy of controls. Prof. Saf. 64, 37–40.
Muller-Ramirez, C., Squibb, K., Mcdiarmid, M., 2017. Measuring extent of surface contamination produced by the handling of antineoplastic drugs in low to middle income country oncology health care settings. Arch. Environ. Occup. Health 22, 289–298.
National Institute for Occupational Safety and Health, 2004. NIOSH Alert: Preventing Occupational Exposures to Antineoplastic and Other Hazardous Drugs in Health Care. Department of Health and Human Services, Centers for Disease Contol and Prevention, National Institute for Occupational Safety and Health, Cincinnati, OH.
National Institute for Occupational Safety And Health (Ed.), 2014. *NIOSH List of Antineoplastic and Other Hazardous Drugs in Healthcare Settings 2014,* Cincinnati, OH: Department of Health and Human Services. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.
National Institute for Occupational Safety and Health, 2020. In: Connor, T., Mackenzie, B., Debord, D., Trout, D., O'callaghan, J., Ovesen, J., Whittaker, C. (Eds.), NIOSH List of Hazardous Drugs in Healthcare Settings 2020 (Draft). National Institute for Occupational Safety and, Cincinnati, OH (Health, DHHS (NIOSH).
National Institute for Occupational Safety and Health. 2022. *Hierarchy of controls* [Online]. Washington, DC, United States: US Department of Health and Human Services. Available: https://www.cdc.gov/niosh/topics/hierarchy/default.html [Accessed 22nd December 2022].

National Institute for Occupational Safety and Health, 2023. In: Hodson, L., Ovesen, J., Couch, J., Hirst, D., Lawson, C., Lentz, T., Mackenzie, B., Mead, K. (Eds.), Managing Hazardous Drug Exposures: Information for Healthcare Settings. US Department for Health and Human Services, Cincinnati, OH (Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH)).
Nguyen, N., Vallet, V., Bouchoud, L., Falaschi, L., Rudaz, S., Bonnabry, P., Fleury-Souverain, S., 2024. Assessment of the surface contamination of the primary packaging of oral antineoplastic drugs and secondary packaging of chemotherapy preparations at a Swiss hospital. J. Oncol. Pharm. Pract. 10781552241250010.
Nichol, K., Bigelow, P., O'brien-Pallas, L., Mcgeer, A., Manno, M., Holness, D., 2008. The individual, environmental, and organizational factors that influence nurses' use of facial protection to prevent occupational transmission of communicable respiratory illness in acute care hospitals. Americal Journal of Infection Control 36, 481–487.
Nieweg, R., de Boer, M., Dubbleman, R., Gall, H., Hesselman, G., Lenssen, P., van Maanen, L., Majoor, P., Ouwerkerk, J., Slegt, J., 1994. Safe handling of antineoplastic drugs. Cancer Nurs. 17, 501–511.
Nouri, A., Seyed Javadi, M., Iranijam, E., Aghamohammadi, M., 2021. Improving nurses' performance in the safe handling of antineoplastic agents: a quasi-experimental study. BMC Nursing 20, 1–5.
Nurgat, Z., Lawrence, M., Elhassan, T., Al Nahedh, M., Ashour, M., Alaboura, D., Al-Jazairi, A., Al-Jedai, A., 2019. Comparison of closed system transfer devices for turnaround time and ease of use. J. Oncol. Pharm. Pract. 25, 1142–1151.
Nwagbo, S., Ilesanmi, R., Ohaeri, B., Oluwatosin, A., 2017. Knowledge of chemotherapy and occupational safety measures among nurses in oncology units. Journal of Clinical Sciences 14, 131–137.
Occupational Safety and Health Administration, 1986. Work Practice Guidelines for Personnel Dealing with Cytotoxic (Antineoplastic) Drugs. DC, Occupational Safety and Health Administration Instructional Publications, Washington.
Oncology Nursing Society, 1989. Safe Handling of Cytotoxic Drugs. Pittsburgh, ONS.
Orujlu, S., Habibzadeh, H., Sakhvidi, M., Hajaghazadeh, M., 2016. Knowledge, attitude, and performance of oncology nurses handling antineoplastic drugs in hospitals of Urmia University. Iran. *International Journal of Occupational Hygiene* 8, 14–21.
Page, M., McKenzie, J., Bossuy, P., Boutron, I., Hoffman, T., Mulrow, C., Shamseer, L., Tetzlaff, J., Akl, J., Brennan, S., Chou, R., Glanville, J., Grimshaw, J., Hróbjartsson, A., Lalu, M., Li, T., Loder, E., Mayo-Wilson, E., Mcdonald, S., McGuinness, L., Stewart, L., Thomas, J., Tricco, A., Welch, V., Whiting, P., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372.
Pan American Health Organization. 2013. *Safe Handling of Hazardous Chemotherapy Drugs in Limited-Resource Settings* [Online]. https://iris.paho.org/handle/10665.2/28554: World Health Organization. Available: https://iris.paho.org/handle/10665.2/28554 [Accessed 13th February 2024].
Pender, N., Murdaugh, C., Parsons, M., 2015. Health Promotion in Nursing Practice. Upper Saddle River, N.J., Pearson.
Pirot, C., Benoist, H., Saint-Lorant, G., 2023. Impact of lack of knowledge on risk perception and protective practices of home nurses handling antineoplastic drugs. J. Oncol. Pharm. Pract. 1–7. Online ahead of print,.
Polovich, M., 2020. USP general chapter <800>: considerations for oncology nursing practice. Semin. Oncol. Nurs. 36, 151022.
Polovich, M., Clark, P., 2012. Factors influencing oncology nurses' use of hazardous drug safe-handling precautions. Oncol. Nurs. Forum 39, E299–E309.
Polovich, M., Martin, S., 2011. Nurses' use of hazardous drug-handling precautions and awareness of national safety guidelines. Oncol. Nurs. Forum 38, 18–26.
Polovich, M., Olsen, M. (Eds.), 2018. Safe Handling of Hazardous Drugs. Oncology Nursing Society, Pittsburgh, United States.
Power, L., 2013. Closed-System Transfer Devices for Safe Handling of Injectable Hazardous Drugs. Pharmacy Practice News, June, pp. 1–16.
Power, L., Coyne, J., 2018. ASHP guidelines on handling hazardous drugs. Am. J. Health-Syst. Pharm. 75, 1996–2031.
Rizalar, S., Tural, E., Altay, B., 2012. Nurses' protective measures during chemotherapy preparation and administration in Turkey. Int. J. Nurs. Pract. 18, 91–98.
Rogers, B., 1987. Work practices of nurses who handle antineoplastic agents. AAOHN J. 35, 24–31.
SA Health 2015. Cytotoxic drugs and related waste: A risk management guide for South Australian health services. *In:* MEDICINES AND TECHNOLOGY POLICY AND PROGRAMS (ed.). Adelaide: Government of South Australia.
Shang, J., Friese, C., Wu, E., Aiken, L., 2013. Nursing practice environment and outcomes for oncology nursing. Cancer Nurs. 36, 206–212.
Silver, S., Steege, A., Boiano, J., 2016. Predictors of adherence to safe handling practices for antineoplastic drugs: A survey of hospital nurses. J. Occup. Environ. Hyg. 13, 203–212.
Spader, C., 2007. A dangerous delusion: nurses who handle hazardous drugs need safety alert. Nurs. Spectr. 19A, 22–23.
Srisintorn, W., Geater, A., Polovich, M., Thongsuksai, P., 2021. Factors influencing precautions against antineoplastic drug exposure among nurses and nurse assistants in Thailand. International Archives of Occupational & Environmental Health 94, 813–822.
Stajich, G., Barnett, C., Turner, S., Henderson, C., 1986. Protective measures used by oncologic office nurses handling parenteral antineoplastic agents. Oncol. Nurs. Forum 13, 47–49.
Teng, C., Shyu, Y., Chiou, W., Fan, H., Lam, S., 2010. Interactive effects of nurse-experienced time pressure and burnout on patient safety: a cross- sectional survey. Int. J. Nurs. Stud. 47, 1442–1450.
Therapeutic Guidelines Limited. 2023a. *Gastrointestinal symptoms in palliative care* [Online]. Available: www.tg.org.au.acs.hcn.com.au [Accessed 28th February 2024].
Therapeutic Guidelines Limited. 2023b. *Oesophageal infections* [Online]. Available: www.tg.org.au.acs.hcn.com.au [Accessed 28th Februrary 2024].
Topcu, S., Beser, A., 2017. Oncology nurses' perspectives on safe handling precautions: a qualitative study. Contemp. Nurse 53, 271–283.
Türk, M., Davas, A., Cicekliogl u, M., Sacaklioglu, F., Mercan, T., 2004. Knowledge, attitude and safe behaviour of nurses handling cytotoxic anticancer drugs in Ege University Hospital. Asian Pac. J. Cancer Prev. 5, 164–168.
United States Pharmacopeia. 2020. *USP general chapter <800>. Hazardous drugs - Handling in healthcare settings* [Online]. Available: https://www.usp.org/compounding/general-chapter-hazardous-drugs-handling-healthcare [Accessed 25th May 2024].
Valanis, B., Browne, M., 1985. Use of protection by nurses during occupational handling of antineoplastic drugs. NITA (Journal of the National Intravenous Therapy Association) 8, 218–222.
Valanis, B., Shortridge, L., 1987. Self protective practices of nurses handling antineoplastic drugs. Oncol. Nurs. Forum 14, 23–27.
Valanis, B., Mcneil, V., Driscoll, K., 1991. Staff members' compliance with their facility's antineoplastic drug handling policy. Oncol. Nurs. Forum 18, 571–576.
Valanis, B., Vollmer, W., Labuhn, K., Glass, A., Corelle, C., 1992. Antineoplastic drug handling protection after OSHA guidelines. Comparison by profession, handling activity, and work site. J. Occup. Med. 43, 149–155.
Victorian Therapeutics Advisory Group. 2021. *Victorian framework: Handling of hazardous medicines* [Online]. https://www.victag.org.au/VicTAG_Handling_of_Hazardous_Medicine_Framework_Nov_2021_Final.pdf: VicTAG. [Accessed 25th May 2024].
Vogus, T., Sutcliffe, K., 2007. The safety organizing scale: development and validation of a behavioral measure of safety culture in hospital nursing units. Med. Care 45, 46–54.
Walton, A., Bush, M., Douglas, C., Allen, D., Polovich, M., Spasojevic, I., 2020. Surface contamination with antineoplastic drugs on two inpatient oncology units. Oncol. Nurs. Forum 47, 263–272.
Weber, D., Babcock, H., Hayden, M., Wright, S., Murthy, A., Guzman-Cottrill, J., Haessler, S., Rock, C., van Schooneveld, T., Forde, C., Logan, L., Malani, A., Henderson, D., 2020. Universal pandemic precautions—an idea ripe for the times. Infection Control & Hospital Epidemiology 41, 1321–1322.
Yodaiken, R., Bennett, D., 1986. OSHA work-practice guidelines for personnel dealing with cytotoxic (antineoplastic) drugs. Occupational safety and health administration. Am. J. Hosp. Pharm. 43, 1193–1204.
Yun, J., Park, J., 2016. Oncology nurses' knowledge of safety guidelines and compliance with safe handling of antineoplastic agents in a tertiary hospital. Asian Oncology Nursing 16, 251–260.
Zayed, H., Saied, S., El-Sallamy, R., Shehata, W., 2019. Knowledge, attittudes and practices of safe handling of cytotoxic drugs among oncology nurses in Tanta University hospitals. Egyptian Journal of Occupational Medicine 43, 75–92.
Zhao, D., Mccoy, A.P., Kleiner, B.M., Smith-Jackson, T.L., 2015. Control measures of electrical hazards: an analysis of construction industry. Saf. Sci. 77, 143–151.
Zimmer, J., Hartl, S., Standfus, K., Möhn, T., Bertsche, A., 2017. Handling of hazardous drugs – effect of an innovative teaching session for nursing students. Nurse Educ. Today 49, 72–78.