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Factors impacting closure of beds and delays in cancer treatment: Insights from the European Cancer Nursing Index 2022 survey

Gianluca Catania [a], Marco Di Nitto [a,*], Helena Ullgren [b,d,e], Lena Sharp [c,d]

[a] Department of Health Sciences – University of Genova, Italy
[b] Karolinska Institute, Department of Oncology-Pathology, Sweden
[c] Regional Cancer Centre Stockholm Gotland, Lindhagensgatan 98, Stockholm, 112 18, Sweden
[d] Department of Nursing, Umeå University, Umeå, 901 87, Sweden
[e] Karolinska Comprehensive Cancer Center, ME HHLH, Sweden

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ABSTRACT

Purpose: The European Cancer Nursing Index (ECNI) 2022 survey identified critical challenges in cancer nursing across Europe. One part of the survey, presented here, aimed at describing European cancer nursing staffing and exploring factors associated with bed closures and cancer treatment delays due to nursing shortages.
Methods: A secondary analysis of the European Cancer Nursing Index 2022 dataset was conducted, including responses from 436 cancer nurses across 29 European countries. Two multivariable logistic regression models were performed to assess the association between workforce-related variables and (1) bed closures and (2) delays in cancer treatment. Independent variables included nurse-to-patient ratio, advanced cancer nursing roles, inpatient setting, preparation of hazardous drugs, and nurse-led care.
Results: Nearly 18 % (n = 80) of respondents reported bed closures and treatment delays in the previous year due to nursing shortages. Logistic regression showed that nurses preparing hazardous drugs at their workplaces, rather than at a pharmacy/lab, were over twice as likely to report treatment delays (OR = 2.16, 95 % CI: 1.24–3.82, p = 0.007). Moreover, each additional patient per nurse increased the likelihood of reporting cancer treatment delay by 9 % (OR = 1.09, 95 % CI: 1.01–1.17, p = 0.026).
Conclusions: Findings highlight the impact of excessive workload and unsafe drug preparation practices on timely cancer care delivery. Centralizing hazardous drug preparation and optimizing staffing may reduce delays and improve patient safety. Further research is needed to understand systemic factors behind bed closures and to inform workforce planning strategies across oncology settings.

1. Introduction

Cancer nurses are essential members of multidisciplinary cancer care teams, contributing to the delivery of safe, effective, and patient-centred care across all phases of the cancer continuum (Drury et al., 2023). The role of cancer nursing is especially relevant also in cancer prevention, particularly in cancer screening and educating the general population (Liebermann et al., 2023). This shift underscores the need to optimise nursing roles to meet rising care demands of cancer patients and to maintain quality and continuity of care, particularly amid persistent nursing shortages across Europe (Molassiotis et al., 2021). Advanced practice models, such as nurse-led clinics, have demonstrated benefits in improving patient outcomes, increasing satisfaction, and enhancing service efficiency. Nevertheless, their implementation remains inconsistent, hindered by variability in training, regulation, and professional recognition (Molassiotis et al., 2021). Alongside workforce challenges, occupational safety concerns persist. Exposure to hazardous cancer drugs poses well-documented health risks for nurses, including reproductive toxicity and carcinogenicity (Hodson et al., 2023; Yu, 2020). Despite the availability of safety protocols and personal protective equipment in many settings, recent findings indicate substantial gaps in protective measures, especially regarding staff education and safeguards during pregnancy and breastfeeding (Sharp et al., 2024).

Notably, the preparation of hazardous drugs by nurses rather than pharmacy staff remains common in some European institutions, potentially contributing to care inefficiencies and increased treatment delays.

* Corresponding author. Department of Health Sciences, University of Genoa. Via A. Pastore, Genoa, 16132, Italy.
E-mail addresses: gianluca.catania@unige.it (G. Catania), marco.dinitto@unige.it (M. Di Nitto), helena.ullgren@ki.se (H. Ullgren).

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Advocacy efforts led by the European Oncology Nursing Society (EONS) stress the importance of addressing these issues through targeted policy, education, and workforce interventions (European Oncology Nursing Society, 2023).

This study builds on this body of evidence by examining how nursing workforce characteristics relate to cancer therapy delays and bed closures due to staff shortages. Indeed, previous literature found that an adequate workforce is characterised by a nurse-to-patients ratio of 1:6 and additional patients can lead to worse patients outcomes, for example increasing the likelihood of mortality (McHugh et al., 2021). Using secondary analysis of data from the 2022 European Cancer Nursing Index (ECNI) (Sharp et al., 2024), this study aims to identify organisational risk factors and inform strategies to promote safe, timely, and sustainable cancer nursing practice across Europe, as well as organizational strategies that enhance both patient outcomes and nurse wellbeing.

Building on prior evidence, the aim of this study was to describe the European cancer nursing staffing levels and to explore factors associated with beds closure and cancer treatment delays due to nursing shortage.

2. Methods

This was a secondary analysis of the ECNI developed by the EONS (Sharp et al., 2024). The guidelines of the Consensus-Based Checklist for Reporting of Survey Studies (CROSS) statement (Sharma et al., 2021) were followed.

2.1. Participants and setting

Between May and December 2022, cancer nurses throughout Europe were invited to participate in an anonymous online survey via a link posted on the EONS website (the survey can be retrieved here: https://www.cancernurse.eu/ecni). This invitation was disseminated through various EONS channels, including meetings, newsletters, social media posts, and emails. Only nurses working within the WHO European Region were eligible, while other healthcare professionals and nurses from outside the region were excluded. In addition, national cancer nursing organizations were contacted and encouraged to share the survey invitation with their members. To ensure accessibility, the survey and information letter were developed in English and then translated by native speaking cancer nursing experts into 16 European languages: Croatian, Czech, Dutch, Estonian, Finnish, French, German, Greek, Icelandic, Italian, Polish, Portuguese, Russian, Spanish, Swedish, and Turkish. Responding nurses could choose which language they preferred to respond in. After data collection, all responses were translated back into English and subsequently coded for analysis. A total of 630 cancer nurses from 29 countries participated to the survey, with the largest numbers from Sweden (n = 99), Italy (n = 98), and Spain (n = 95) (Sharp et al., 2024). The sample included a diverse range of countries across northern, southern, western, and eastern Europe, enabling a broad representation of clinical settings and healthcare systems within the region.

2.2. Survey questionnaire

The ECNI 2022 included 22 items distributed in the following dimensions: 1) Education and Career Development (5 items); 2) Patient and Occupational Safety (8 items); 3) Recognition (4 items); 4) Working Conditions, Retention and Impact (4 items); and 5) Staffing levels (6 items). Moreover, a demographic section was available (age, gender, country of practice, experience in nursing and cancer care). In this manuscript, the analysis focused on dimension 5 (Staffing levels) which included specific questions referred to the work environment (e.g., How many hours did you work on your last shift? How many patients in total were on your unit on your last shift?), while the main results of the ECNI 2022 can be found elsewhere (Sharp et al., 2024).

2.3. Data analysis

Descriptive statistics were used to analyse demographic characteristics and the scores of selected items from the ECNI 2022 questionnaire. Two multivariable logistic regression models were conducted to examine whether the nurse-to-patient ratio was associated with bed closures (Q20) or delays in cancer treatments (Q21) due to nursing shortages in the past 12 months.

For the purposes of this analysis, both outcome variables were dichotomized to facilitate interpretation and enable the use of binary logistic regression. This decision was made to distinguish between nurses who reported frequent occurrences of bed closures or treatment delays and those who reported infrequent or no occurrences. Specifically, frequent events were defined as responses “It happens every week” and “It happens every month” (coded as 1), while infrequent or no events were defined as “It happens very rarely” and “It never happens” (coded as 0).

Five independent variables were included, as they were hypothesised to be directly associated with the outcomes: nurse-to-patient ratio, presence of an advanced cancer nursing role, working in an inpatient setting, preparation of hazardous drugs in the workplace, and presence of established nurse-led cancer care. The nurse-to-patient ratio was derived from questions H (“Including yourself, how many nurses in total provided direct patient care on your unit during your last shift?”) and I (“How many patients in total were on your unit during your last shift?”). The other independent variables were obtained from question G (“Do you work in an inpatient setting?”), Q4 (“Are advanced cancer nursing roles implemented in your workplace?”), Q12 (“Do nurses prepare hazardous drugs at your workplace?”), and Q16 (“Is nurse-led cancer care established in your organisation?”). Q4 was categorised in two groups (Yes vs No), Q12 was categorised in two groups (It happens vs It never happens) and Q16 was categorised in two groups (Yes vs No).

Before conducting the regression analyses, responses were filtered to include only nurses who: (1) reported providing direct care, (2) did work a day shift during their last shift, and (3) reported a nurse-to-patient ratio of one nurse to 18 patients or fewer. This filter was deemed necessary to remove outliers that could have an impact on results of logistic regression. After filtering, 436 responses were retained for analysis.

Multicollinearity was assessed using the Variance Inflation Factor (VIF), with all values below the commonly accepted threshold of 5, indicating no multicollinearity among the independent variables. The Hosmer–Lemeshow test was also used to assess model fit.

A post-hoc power analysis was performed to determine whether the sample size was adequate. Following the guideline by Bujang et al. (2018), the minimum sample size required for a logistic regression model is calculated as 100 + 50i, where “i” is the number of independent variables. With five independent variables, a minimum of 350 participants was required. The final sample of 436 nurses was therefore sufficient to conduct the analyses.

All analyses were conducted using RStudio© (V. 2025.05.0) and R© (V. 4.4.2) (R CORE TEAM, 2025) and using the packages “Table 1” for descriptive statistics (Rich, 2023), “car” for VIF (Fox and Weisberg, 2019) and “ResourceSelection” for the Hosmer-Lemeshow test (Lele et al., 2024). A complete case analysis was chosen for allowing a straightforward interpretation of results. Results from the logistic regression models were presented as odds ratios (ORs) with 95 % confidence intervals (CIs) and p-values.

3. Results

The ECNI 2022 survey yielded a total of 630 responses from cancer nurses across 29 countries, which complete description can be found elsewhere (Sharp et al., 2024). Regarding the staffing levels section of the survey, most of the respondents reported to work in direct patient care (n = 479, 76 %) and more than half reported to work in an inpatient

Table 1
Descriptives of the Workforce statistics section of the ECNI2022 survey (n = 630).

	N (%)	Mean (SD)	Missing (%)
Do you work in direct patient care?			1 (0.2 %)
No	150 (23.8 %)		
Yes	479 (76.0 %)		
Do you work in an inpatient setting?			2 (0.3 %)
No	293 (46.5 %)		
Yes	335 (53.2 %)		
Including yourself how many nurses in total, provided direct patient care on your unit during your last shift?		5.61 (4.06)	163 (25.9 %)
How many patients in total were on your unit on your last shift?		26.7 (17.3)	189 (30.0 %)
Nurse-to-patients ratio		6.41 (5.46)	189 (30.0 %)
What was the last shift you worked?			158 (25.1 %)
Night shift	40 (6.3 %)		
Day shift	432 (68.6 %)		
How many hours did you work on your last shift?		8.31 (1.53)	178 (28.3 %)

setting (n = 335, 53.2 %). Considering their last shift, respondents reported a mean of 5.61 (SD = 4.06) nurses dedicated to direct patient care and a mean of 26.7 (SD = 17.3) patients cared by, resulting in a mean nurse-to-patients ratio of 6.41 (SD = 5.46) (Table 1).

3.1. Demographic characteristics of the sample

The filtered dataset was composed by a total of 436 responses. General characteristics of the respondents analysed are reported in Table 2. Specifically, most responders were female (n = 395, 90.6 %) and had worked ≥21 years as a nurse (n = 182, 41.7 %). The sample reported an adequate distribution of years of experience as cancer nurse, with most of the sample having an experience in cancer care of ≤10 years (n = 204, 46.8 %).

3.2. Factors impacting beds closure and cancer treatment delays

Table 3 presents the descriptives of the variables included in the logistic regression models. Almost the 18 % of respondents reported a beds closure (18.3 %) and a cancer treatment delay (17.9 %) due to nursing shortage in the last 12 months. The 39 % of respondents reported preparing hazardous drugs at their workplace, instead of preparing it in hospital pharmacy. More than half of the respondents reported to work in an inpatient setting (n = 246, 56.4 %).

The first logistic regression analysis was conducted to explore the factors associated with bed closures due to nursing shortages in the past 12 months (Q20). None of the predictors were significantly associated with bed closure (Table 4).

The second logistic regression analysis was conducted to explore the factors associated with cancer treatment delay due to nursing shortages in the past 12 months (Q20) (Table 5).

The odds of cancer treatment delay were 2.16 times higher among respondents who reported that nurses prepare hazardous drugs in their workplace (Q12) compared to those who reported it never happens (OR = 2.16, 95 % CI: 1.24–3.82, p = 0.007). Moreover, each additional patient per nurse increased the likelihood of reporting cancer treatment delay by 9 %. (OR = 1.09, 95 % CI: 1.01–1.17, p = 0.026). The Hosmer-Lemeshow goodness-of-fit test yielded a chi-squared statistic of 8.764 with 8 degrees of freedom and a p-value of 0.363, suggesting that the model fits the data well.

Table 2
Sociodemographic characteristics of the sample (n = 436).

	N (%)	Missing
Sex		
Female	395 (90.6 %)	
Male	41 (9.4 %)	
Age		2 (0.5 %)
≤30	57 (13.1 %)	
≥61	15 (3.4 %)	
31-40	144 (33.0 %)	
41-50	125 (28.7 %)	
51-60	93 (21.3 %)	
Years as a nurse		
≤5	41 (9.4 %)	
≥21	182 (41.7 %)	
11-15	66 (15.1 %)	
16-20	66 (15.1 %)	
6-10	81 (18.6 %)	
Years as a cancer nurse		
≤5	101 (23.2 %)	
≥21	82 (18.8 %)	
11-15	93 (21.3 %)	
16-20	57 (13.1 %)	
6-10	103 (23.6 %)	
Country		
Andorra	1 (0.2 %)	
Austria	5 (1.1 %)	
Belgium	16 (3.7 %)	
Croatia	9 (2.1 %)	
Cyprus	4 (0.9 %)	
Denmark	2 (0.5 %)	
Estonia	6 (1.4 %)	
Finland	10 (2.3 %)	
Georgia	12 (2.8 %)	
Germany	19 (4.4 %)	
Greece	23 (5.3 %)	
Iceland	3 (0.7 %)	
Ireland	19 (4.4 %)	
Italy	62 (14.2 %)	
Lithuania	1 (0.2 %)	
Malta	2 (0.5 %)	
Norway	11 (2.5 %)	
Other	10 (2.3 %)	
Poland	8 (1.8 %)	
Portugal	26 (6.0 %)	
San Marino	1 (0.2 %)	
Serbia	1 (0.2 %)	
Slovenia	5 (1.1 %)	
Spain	75 (17.2 %)	
Sweden	63 (14.4 %)	
Switzerland	12 (2.8 %)	
The Netherlands	18 (4.1 %)	
United Kingdom	12 (2.8 %)	

4. Discussion

The analysis of therapy delays highlights two significant risk factors: the frequent preparation of hazardous drugs by nurses (OR = 2.16, p = 0.007) and a higher nurse-to-patient ratio (OR = 1.09, p = 0.026). These findings suggest that inadequate staffing and excessive workload may compromise the timely administration of cancer therapies.

Specifically, when nurses prepare hazardous drugs within their workplace instead of receiving the drugs directly from the hospital pharmacy, the likelihood of cancer treatment delay due to nursing shortage more than doubled. This confirms the necessity of safe handling of hazardous drugs (Bernabeu-Martínez et al., 2018) to avoid inefficiencies in therapy administration. Ensuring that nurses are not overburdened with drug preparation responsibilities may help mitigate these delays and improve care efficiency. This interpretation is further supported by Coyne et al. (2019), who highlight that chemotherapy

Table 3
Descriptives of the variables included in the logistic regression models (n = 436).

	N (%)	Mean (SD)	Missing (%)
Q4. Advanced cancer nursing roles implemented			1 (0.2 %)
No	215 (49.3 %)		
Yes	220 (50.5 %)		
Q12. Do nurses prepare hazardous drugs at your workplace?			4 (0.9 %)
Never	262 (60.1 %)		
Sometimes or often	170 (39.0 %)		
Q16. Nurse-led cancer care established in your organisation			34 (7.8 %)
No	181 (41.5 %)		
Yes	221 (50.7 %)		
G. Do you work in an inpatient setting?			
No	190 (43.6 %)		
Yes	246 (56.4 %)		
Nurse-to-patients ratio		5.58 (3.55)	43 (9.9 %)
Q20. Beds closed due to cancer nursing shortages in the last 12 months			8 (1.8 %)
It happens rarely	348 (79.8 %)		
It happens weekly/monthly	80 (18.3 %)		
Q21. Cancer treatments delayed due to cancer nursing shortages in the last 12 months			5 (1.1 %)
It happens rarely	353 (81.0 %)		
It happens weekly/monthly	78 (17.9 %)		

Table 4
Results of the logistic regression considering beds closure due to nursing shortage in the last 12 months as dependent variable (n = 436).

	OR	p	95 % CI
Q4 (Yes vs No)	1.61	0.109	0.90–2.93
Q12 (It happens vs It never happens)	1.50	0.141	0.87–2.57
Q16 (Yes vs No)	1.11	0.735	0.62–2.00
Nurse-to-patients ratio	1.02	0.662	0.94–1.10
G (Yes vs No)	1.04	0.893	0.60–1.82

Notes: Q4: "Are advanced cancer nursing roles implemented in your workplace?"; G: "Do you work in an inpatient setting?"; Q12: "Do nurses prepare hazardous drugs at your workplace?"; Q16: "Is nurse-led cancer care established in your organisation?".

Table 5
Results of the logistic regression considering cancer treatment delay due to nursing shortage in the last 12 months as dependent variable (n = 436).

	OR	P	95 % CI
Q4 (Yes vs No)	0.97	0.922	0.52–1.80
Q12 (It happens vs It never happens)	2.16	0.007	1.24–3.82
Q16 (Yes vs No)	0.93	0.807	0.50–1.72
Nurse-to-patients ratio	1.09	0.026	1.01–1.17
G (Yes vs No)	0.91	0.761	0.51–1.64

Notes: Q4: "Are advanced cancer nursing roles implemented in your workplace?"; G: "Do you work in an inpatient setting?"; Q12: "Do nurses prepare hazardous drugs at your workplace?"; Q16: "Is nurse-led cancer care established in your organisation?".

administration is a complex and risk-laden task requiring structured protocols and appropriate resourcing (Coyne et al., 2019). Their integrative review emphasizes that nurses' involvement in hazardous drug preparation can introduce workflow disruptions and increase the potential for medication errors, especially in the absence of standardized procedures and adequate training. They advocate for organizational safeguards such as centralized preparation, standardized computer-generated orders, barcode systems, and dedicated pharmacy support to reduce nursing burden and ensure safer, more efficient therapy delivery. These findings reinforce the argument that reallocating the preparation of hazardous drugs to specialized pharmacy staff not only protects nurses from occupational risks but also reduces inefficiencies that contribute to treatment delays.

Moreover, occupational safety concerns related to hazardous drug preparation are widely recognized as a critical issue in cancer nursing. Challinor et al. (2020) highlight that exposure to cytotoxic agents and the lack of standardized safety protocols remain significant barriers to a sustainable cancer nursing workforce (Challinor et al., 2020). The combination of workload strain and inadequate protective measures may not only increase therapy delays but also contribute to nurse dissatisfaction and attrition. Strengthening safety guidelines and reallocating responsibilities to specialized pharmacy staff could be viable strategies to improve efficiency while ensuring the protection of nursing personnel.

Although the effect of the nurse-to-patient ratio is smaller (OR = 1.09), it remains statistically significant, indicating that for each additional patient per nurse, the likelihood of reporting cancer treatment delay rise by approximately 9 %. This finding suggests that a higher nursing workload is directly associated with a greater likelihood of treatment delays. As the patient load increases, nurses may experience difficulties in balancing multiple care demands, leading to interruptions and inefficiencies in therapy administration. Higher nursing workload can also lead to worse outcomes for nursing personnel, such as increasing intention to leave and burnout (Shah et al., 2021). Moreover, it should be considered that an unbalanced nurse-to-patients ratio has been associated with many negative outcomes for patients, as it can increase mortality (Catania et al., 2024; McHugh et al., 2021) and missed nursing care (Caponnetto et al., 2025; Nantsupawat et al., 2022). Lastly, as the nurse-to-patient-ratio can be related to all these outcomes, it should be considered a priority for hospital managers, as it can have an impact on net costs (Griffiths et al., 2023).

The EONS Cancer Nursing Education Framework underscores the necessity of staffing strategies that balance workload and patient safety (European Oncology Nursing Society, 2022). Similarly, Young et al. (2020) emphasize the crucial role of cancer nurses in care coordination and clinical leadership to maintain continuity of care (Young et al., 2020).

These findings are consistent with Challinor et al. (2020), who stress that nursing shortages and high patient-to-nurse ratios are major contributors to delays in cancer treatment, particularly in settings with limited resources (Challinor et al., 2020). Their review of global cancer nursing workforce challenges indicates that without targeted workforce planning, cancer nurses will continue to face excessive workloads, leading to negative consequences for both patient outcomes and staff retention. Addressing these shortages through structured recruitment and retention strategies, including leadership development and workload optimization, is essential to prevent disruptions in cancer care delivery.

In addition to therapy delays, the analysis examined factors associated with bed closures due to cancer nursing shortages. The results indicate that none of the investigated variables reached statistical significance in predicting bed closures. These findings suggest that bed closures due to nursing shortages may be influenced by broader systemic factors, such as institutional policies, workforce planning strategies, and overall healthcare resource allocation (Hsia et al., 2011), rather than the specific workforce characteristics analysed in this study.

4.1. Implications for practice

The findings of this study emphasize the need for optimizing cancer nursing workload and staffing policies to reduce therapy delays. Healthcare institutions should prioritize adequate nurse staffing, as evidence-based models indicate that an optimized distribution of care responsibilities can mitigate excessive workloads and minimize inefficiencies.

Implementing structured workforce planning is essential to prevent disruptions in cancer care delivery, particularly in contexts where nurse-to-patient ratios are high. Enhancing drug preparation protocols could also contribute to improved efficiency in therapy administration. The strong association between hazardous drug preparation and therapy delays suggests that centralizing drug preparation within hospital pharmacies or implementing automation technologies may alleviate the burden on nurses, allowing them to focus more on direct patient care. Strengthening interprofessional collaboration, particularly between cancer nurses and pharmacists, could further facilitate smoother workflows and reduce delays.

Ensuring compliance with occupational safety measures is another key implication. As highlighted by Challinor et al. (2020), exposure to hazardous drugs remains a serious concern for cancer nurses, and the implementation of standardized safety protocols, such as proper use of personal protective equipment, is critical to safeguard healthcare workers.

Investing in mandatory training programs on safe drug handling and risk reduction strategies can enhance adherence to safety measures and protect nursing personnel (Challinor et al., 2020). Similarly, Coyne et al. (2019) emphasize the need for structured education programs to ensure nurses are adequately trained in chemotherapy administration and safety requirements, highlighting the importance of continuous learning and skill development in cancer nursing (Coyne et al., 2019). Their review identifies gaps in existing training programs and supports the implementation of standardized guidelines to improve both safety and efficiency in chemotherapy administration.

In addition, leadership development and nurse retention strategies should be prioritized to maintain a sustainable cancer nursing workforce. Providing career advancement opportunities, professional recognition, and fostering a supportive work environment are essential measures to enhance job satisfaction and retention rates. As noted by Challinor et al. (2020), effective workforce retention strategies not only improve job sustainability but also contribute to better patient outcomes by ensuring continuity of care in cancer settings (Challinor et al., 2020).

4.2. Limitations

This study has some limitations. First, one limitation of this study is the temporal mismatch between the nurse-to-patient ratio, which was measured based on the nurses' most recent shift, and the dependent variables, which refer to events occurring over the past 12 months. Although the last-shift ratio can serve as a proxy for typical staffing conditions, it may not fully capture fluctuations in staffing patterns across the entire year. As such, caution should be used when interpreting causality or long-term associations based on this variable. Second, the analysis assumed a linear relationship between staffing levels and the outcomes of interest. This was not assessed in the current study and should be considered a limitation, as it could influence the interpretation of associations between staffing and the outcomes assessed. Third, the study did not include data on skill mix, which may have hindered potential effects on the outcomes. Moreover, there was not sufficient information for including countries as a predictor of bed closures and treatment delays, due to the sparse responses of participants. All these aspects should be further explored in future studies. Additionally, the cross-sectional design of the study prevents the establishment of causal relationships between variables. As such, while associations were observed, the directionality of these relationships cannot be confirmed. However, it should be noted that the primary aim of the study was descriptive. Therefore, the logistic regression models were not intended to establish causality, but rather to offer a more in-depth exploration of associations among variables of interest. Finally, a limitation lies in the survey-based design of the study, which may be subject to self-report bias, recall bias and variations in interpretation of the questions across different settings, although the survey was pilot tested to ensure accuracy of questions and unique interpretation by respondents. Despite this, a notable strength is the inclusion of data from multiple European countries, providing a broad and diverse perspective on the issues examined.

5. Conclusion

In summary, the findings reinforce that hazardous cancer drugs preparation is an integral component of cancer nursing practice. The EONS Safety Manifesto highlights the crucial role of cancer nurses in ensuring the safe preparation and administration of chemotherapy. Cancer nurses play a central role in patient safety by adhering to standardized protocols, having access to written guidelines (e.g., the EU Directive, 2022/431), receiving appropriate training before handling hazardous drugs, and using Personal Protective Equipment (PPE), Closed System Transfer Devices (CSTDs), and systematic surface wipe tests. Furthermore, the manifesto stresses that staffing shortages can compromise patient safety, aligning with our findings that higher nurse-to-patient ratios are associated with therapy delays (European Oncology Nursing Society, 2019). Investing in workforce sustainability and continuous training is essential to maintaining safe and timely chemotherapy delivery. Furthermore, while this study found a strong association between nurse workload and therapy delays, no clear predictors for bed closures emerged, suggesting the need for further investigation into broader systemic influences. Future research should explore the impact of technological interventions, interventions that improve safety culture in oncology settings and interprofessional collaboration in mitigating therapy delays and improving cancer nursing workflows.

CRediT authorship contribution statement

Gianluca Catania: Writing – review & editing, Writing – original draft, Validation, Formal analysis, Conceptualization. **Marco Di Nitto:** Writing – review & editing, Writing – original draft, Validation, Formal analysis. **Helena Ullgren:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Lena Sharp:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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References

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.

Bujang, M.A., Sa'At, N., Sidik, T., Joo, L.C., 2018. Sample size guidelines for logistic regression from observational studies with large population: emphasis on the

accuracy between statistics and parameters based on real life clinical data. Malays. J. Med. Sci. 25, 122-130.
Caponnetto, V., Di Nitto, M., Cesare, M., Iovino, P., Longobucco, Y., Marcomini, I., Zaghini, F., Alvaro, R., Burgio, A., Cicolini, G., Drennan, J., Lancia, L., Landa, P., Manara, D.F., Mazzoleni, B., Rasero, L., Rocco, G., Zega, M., Sasso, L., Bagnasco, A., 2025. Factors associated with missed nursing care in home care setting: insights from the AIDOMUS-IT multicentre study. Health Soc. Care Community 2025, Article ID 6664667.
Catania, G., Zanini, M., Cremona, M.A., Landa, P., Musio, M.E., Watson, R., Aleo, G., Aiken, L.H., Sasso, L., Bagnasco, A., 2024. Nurses' intention to leave, nurse workload and in-hospital patient mortality in Italy: a descriptive and regression study. Health Policy 143, 105032.
Challinor, J.M., Alqudimat, M.R., Teixeira, T.O.A., Oldenmenger, W.H., 2020. Oncology nursing workforce: challenges, solutions, and future strategies. Lancet Oncol. 21, e564–e574.
R CORE TEAM, R, 2025. R: A Language and Environment for Statistical Computing.
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.
Drury, A., Sulosaari, V., Sharp, L., Ullgren, H., De Munter, J., Oldenmenger, W., 2023. The future of cancer nursing in Europe: addressing professional issues in education, research, policy and practice. Eur. J. Oncol. Nurs. 63, 102271.
EUROPEAN ONCOLOGY NURSING SOCIETY, 2019. Safety manifesto [online]. Available. https://www.cancernurse.eu/advocacy-wg-1. (Accessed 14 April 2025).
EUROPEAN ONCOLOGY NURSING SOCIETY, 2022. Cancer nursing education Framework [online]. Available. https://www.cancernurse.eu/cancer-nursing-education-framework. (Accessed 14 April 2025).
EUROPEAN ONCOLOGY NURSING SOCIETY, 2023. EONS advocacy toolkit [online]. Available. https://www.cancernurse.eu/advocacy-wg-1. (Accessed 14 April 2025).
Fox, J., Weisberg, S., 2019. An R companion to applied regression. Thousand Oaks CA. Sage.
Griffiths, P., Saville, C., Ball, J., Dall'Ora, C., Meredith, P., Turner, L., Jones, J., 2023. Costs and cost-effectiveness of improved nurse staffing levels and skill mix in acute hospitals: a systematic review. Int. J. Nurs. Stud. 147, 104601.
Hodson, L., Ovesen, J., Couch, J., Hirst, D., Lawson, C., Lentz, T.J., Mackenzie, B., Mead, K., 2023. Managing hazardous drug exposures: information for healthcare settings [Online]. Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Available. https://doi.org/10.26616/NIOSHPUB2023130. (Accessed 14 April 2025).
Hsia, R.Y., Kellermann, A.L., Shen, Y.C., 2011. Factors associated with closures of emergency departments in the United States. JAMA 305, 1978–1985.
Lele, S., Keim, J.L., Solymos, P., 2024. ResourceSelection: resource selection (probability) functions for use-availability data [online]. Available. https://github.com/psolymos/ResourceSelection.
Liebermann, E., Sego, R., Vieira, D., Cheng, Q., Xu, B., Arome, M., Azevedo, A., Ginsburg, O., So, W.K.W., 2023. Roles and activities of nurses in cancer prevention and early detection in low- and middle-income countries: a scoping review. Asia Pac. J. Oncol. Nurs. 10, 100242.
Mchugh, M.D., Aiken, L.H., Sloane, D.M., Windsor, C., Douglas, C., Yates, P., 2021. Effects of nurse-to-patient ratio legislation on nurse staffing and patient mortality, readmissions, and length of stay: a prospective study in a panel of hospitals. Lancet 397, 1905–1913.
Molassiotis, A., Liu, X.L., Kwok, S.W., 2021. Impact of advanced nursing practice through nurse-led clinics in the care of cancer patients: a scoping review. Eur. J. Cancer Care 30, e13358.
Nantsupawat, A., Poghosyan, L., Wichaikhum, O.A., Kunaviktikul, W., Fang, Y., Kueakomoldej, S., Thienthong, H., Turale, S., 2022. Nurse staffing, missed care, quality of care and adverse events: a cross-sectional study. J. Nurs. Manag. 30, 447–454.
Rich, B., 2023. table 1: tables of descriptive statistics *in HTML* [online]. Available. https://CRAN.R-project.org/package=table1.
Shah, M.K., Gandrakota, N., Cimiotti, J.P., Ghose, N., Moore, M., Ali, M.K., 2021. Prevalence of and factors associated with nurse burnout in the US. JAMA Netw. Open 4, e2036469.
Sharma, A., Minh Duc, N.T., Luu Lam Thang, T., Nam, N.H., Ng, S.J., Abbas, K.S., Huy, N. T., Marušić, A., Paul, C.L., Kwok, J., Karbwang, J., De Waure, C., Drummond, F.J., Kizawa, Y., Taal, E., Vermeulen, J., Lee, G.H.M., Gyedu, A., To, K.G., Verra, M.L., Jacqz-Aigrain É, M., Leclercq, W.K.G., Salminen, S.T., Sherbourne, C.D., Mintzes, B., Lozano, S., Tran, U.S., Matsui, M., Karamouzian, M., 2021. A consensus-based checklist for reporting of survey studies (CROSS). J. Gen. Intern. Med. 36, 3179–3187.
Sharp, L., Fransson, P., Fowler, M., Ullgren, H., 2024. Aspects of occupational safety: a survey among European cancer nurses. Eur. J. Oncol. Nurs. 70, 102595.
Young, A.M., Charalambous, A., Owen, R.I., Njodzeka, B., Oldenmenger, W.H., Alqudimat, M.R., So, W.K.W., 2020. Essential oncology nursing care along the cancer continuum. Lancet Oncol. 21, e555–e563.
Yu, E., 2020. Occupational exposure in health care personnel to antineoplastic drugs and initiation of safe handling in Hong Kong: a literature review. J. Infusion Nurs. 43, 121–133.