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Original Article

Enhancing Safety Competence among Nurses: A Pre - Experimental Study on the Impact of an Educational Program on Cytotoxic Drug Management and its Outcomes in Safe Pharmacy Practice

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ABSTRACT

Background: Cytotoxic drugs are essential in cancer treatment but pose significant occupational hazards due to their mutagenic, teratogenic, and carcinogenic properties. Nurses are at high risk during drug preparation and administration, and inadequate training contributes to unsafe handling practices. Therefore, this study evaluated the effectiveness of a structured educational program in improving nurses' competence in cytotoxic drug management. **Materials and Methods:** A pre-experimental one-group pretest-post-test design was conducted among 60 staff nurses at a tertiary care teaching hospital in Puducherry, India. Competence was assessed using a validated 25-item structured questionnaire covering preparation, administration, Personal Protective Equipment (PPE), spill management, and waste disposal. The intervention consisted of a 45-min structured educational session based on NIOSH and Oncology Nursing Society guidelines. Data were collected before and seven days after the intervention and analysed using descriptive statistics, paired t-test, and chi-square test. **Results:** Baseline findings revealed that 60% of nurses had inadequate knowledge and only 3.3% demonstrated adequate competence. Following the intervention, 91.7% achieved adequate knowledge, with no participants remaining in the inadequate category. The mean knowledge score significantly increased from 8.62±2.97 to 16.53±1.44, with a mean difference of 7.91 (t=20.684, p<0.001), indicating a highly significant improvement. The effect size (Cohen's d=3.33) demonstrated a very large impact of the intervention. A significant association was found between prior training and post-test knowledge scores (p<0.05), while other demographic variables showed no significant association. **Conclusion:** The structured educational program significantly enhanced nurses' competence in cytotoxic drug management. Regular training and reinforcement strategies are essential to promote occupational safety and improve safe pharmacy practice.

Keywords: Cytotoxic drugs, Educational intervention, Nursing competence, Occupational safety, Oncology nursing.

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INTRODUCTION

Cancer continues to represent a major global health burden, with nearly 19 million new cases reported annually (World Health Organization [WHO], 2023). Cytotoxic (antineoplastic) drugs remain central to cancer treatment; however, their hazardous properties pose occupational risks to healthcare workers. Exposure may occur through inhalation of aerosols, dermal absorption, ingestion, or needle-stick injuries. Chronic exposure has been associated with reproductive toxicity, chromosomal abnormalities, and secondary malignancies (Connor and McDiarmid, 2006; Sessink *et al*., 2011).

International guidelines such as those from the National Institute for Occupational Safety and Health (NIOSH, 2022) and the Oncology Nursing Society (Polovich, 2021) emphasize safe handling practices, including proper Personal Protective Equipment (PPE), closed-system transfer devices, spill management, and safe disposal. Despite available standards, compliance gaps persist, especially in low-resource settings (Martin *et al*., 2018).

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Educational interventions have demonstrated effectiveness in improving nurses' knowledge and adherence to safety practices (Lee *et al.*, 2018; Türk *et al.*, 2021). However, limited empirical evidence exists in Indian tertiary care hospitals assessing structured educational programs integrating nursing and pharmacy collaboration. This study aimed to evaluate the effectiveness of a structured educational program in enhancing nurses' competence in cytotoxic drug management.

MATERIALS AND METHODS

A pre-experimental one-group pretest-post-test design was employed to evaluate the effectiveness of a structured educational program on nurses' competence in cytotoxic drug management. The study was conducted at Mahatma Gandhi Medical College and Research Institute, Puducherry, a tertiary care teaching hospital with active oncology services.

A total of 60 registered staff nurses were recruited using convenience sampling. The sample size was determined using G*Power (effect size=0.5, α=0.05, power=0.80), with a minimum requirement of 54 participants; additional participants were included to account for attrition.

Inclusion criteria comprised registered nurses directly involved in the preparation or administration of cytotoxic drugs and willing to provide informed consent. Nurses in administrative roles, students, interns, and those on long-term leave were excluded.

Data were collected using a validated 25-item structured questionnaire assessing five domains: drug preparation, administration techniques, PPE usage, spill management, and biomedical waste disposal. Each correct response was awarded one mark, with total scores categorized as inadequate (<50%), moderately adequate (50-74%), and adequate (≥75%). Content validity was established through expert evaluation (S-CVI=0.92), and reliability testing yielded a Cronbach's alpha of 0.86.

The intervention consisted of a 45-min structured educational session delivered in small groups using lecture, demonstration, and discussion methods. Content was based on standardized guidelines and included occupational hazards, PPE protocols, safe handling procedures, and documentation practices.

Data collection was conducted in three phases:

- Pretest assessment (Day 1).
- Educational intervention (same day).
- Post-test assessment (Day 7).

Statistical Analysis

Data were coded and entered into Microsoft Excel and analysed using the Statistical Package for the Social Sciences (SPSS) version 26.0. Descriptive statistics, including frequency, percentage, mean, median, and standard deviation, were used to summarize demographic characteristics and knowledge scores. The paired *t*-test was used to compare pretest and post-test mean knowledge scores to determine the effectiveness of the structured educational intervention. The chi-square test was applied to examine the association between post-test knowledge levels and selected demographic variables such as age, gender, years of clinical experience, educational qualification, and prior training in cytotoxic drug handling. A *p*-value of less than 0.05 was considered statistically significant.

Ethical approval was obtained from the Institutional Human Ethics Committee, and written informed consent was secured from all participants. Confidentiality and anonymity of participants' information were strictly maintained throughout the study.

RESULTS

A total of 60 staff nurses participated in the study. The majority were female (86.7%), aged 26-35 years (61.7%), held a B.Sc. Nursing qualification (70%), and had 3-8 years of clinical experience (55%). Only 20% had prior training in cytotoxic drug handling.

Competence Levels

At baseline, knowledge regarding cytotoxic drug management was inadequate among the majority of participants, with 60% classified as inadequate, 36.7% as moderately adequate, and only 3.3% demonstrating adequate competence.

Following the educational intervention, a marked improvement was observed. The proportion of nurses with adequate knowledge increased to 91.7%, while 8.3% remained moderately adequate, and no participants were categorized as inadequate. This shift indicates a substantial enhancement in competence levels after the intervention.

Table 1, Distribution of Competence Levels Regarding Management of Cytotoxic Drugs, shown Knowledge was assessed using a structured questionnaire administered before and after the educational intervention. Competence levels were categorized as inadequate, moderately adequate, and adequate based on predefined scoring criteria. In the pre-test, only 3.3% of participants demonstrated adequate knowledge, while 60% fell into the inadequate category. Following the intervention, 91.7% achieved adequate knowledge, and no participant remained in the inadequate category. The findings indicate a marked improvement in competence levels after the educational program, supporting its effectiveness in strengthening nurses' competence of cytotoxic drug management.

Notably, only 20% of the nurses had previously attended a training program on chemotherapy safety, suggesting an initial gap in structured educational exposure regarding management of safety administration of cytotoxic drugs.

Comparison of Pretest and Post-test Scores

The mean pretest knowledge score was 8.62 (SD=2.97), which increased to 16.53 (SD1.44) in the post-test. The mean difference of 7.91 reflects a considerable improvement in knowledge scores. The paired t-test revealed a statistically highly significant difference between pretest and post-test scores (t=20.684, p<0.001). Additionally, the effect size (Cohen's d=3.33) indicated a very large magnitude of improvement, demonstrating the strong effectiveness of the educational intervention.

Table 2, Comparison of Pretest and Posttest competency Scores Using Paired *t*-Test Showed, Knowledge scores were analysed using mean, median, Standard Deviation (SD), and paired t-test to assess statistical significance. The mean pre-test knowledge score was 8.62 (±2.97), which increased to 16.53 (±1.44) in the post-test, yielding a mean difference of 7.91. The calculated paired *t*-value was 20.684, with a *p*-value<0.001, indicating a highly statistically significant improvement following the intervention. The effect size calculated using Cohen's d was 3.33, indicating a very large magnitude of improvement in nurses' competence following the structured educational intervention. The educational program produced a significant enhancement in competence regarding safe handling of cytotoxic drugs.

Further analysis was conducted to examine associations between post-test knowledge scores and selected demographic variables using the chi-square test. A statistically significant association was observed between prior training in cytotoxic drug handling and post-test knowledge scores (p<0.05). However, no significant associations were found with age, gender, or years of clinical experience. These findings suggest that previous exposure to structured training positively influences knowledge acquisition, while other demographic variables did not significantly affect outcomes. Overall, the results provide strong evidence that the structured educational intervention was effective in improving nurses' competence in cytotoxic drug management

Association with Demographic Variables

Chi-square analysis showed a statistically significant association between prior training in cytotoxic drug handling and higher post-test knowledge scores (p<0.05). However, no significant associations were found with age, gender, educational qualification, or years of experience.

DISCUSSION

The present study examined whether a structured educational program could improve nurses' competence in the safe management of cytotoxic drugs. The findings clearly demonstrate a substantial and statistically significant improvement in knowledge after the intervention, thereby supporting the stated Hypothesis (H_1) that a significant difference would exist between pre-test and post-test scores. The marked rise in adequate knowledge levels after the educational session indicates that structured training is an effective strategy for strengthening safety competence.

The results of this study are consistent with previous research in the field. Sahu *et al.* (2017) reported a significant increase in oncology nurses' knowledge scores following structured training, while Polovich and Clark (2012) found that educational initiatives improved adherence to Personal Protective Equipment (PPE) use and safety guidelines. International evidence also supports these findings. Türk *et al.* (2021) observed improved compliance with safe handling practices after training, and Lee *et al.* (2018) documented enhanced knowledge and adherence among nurses in South Korea following structured educational interventions. Similarly, Rao and Manjunath (2019) reported substantial improvements in knowledge levels among Indian nurses after continuous education programs. The consistency of these findings across diverse healthcare systems strengthens the conclusion that education is a critical determinant of safe cytotoxic drug management.

Occupational exposure to cytotoxic drugs has been recognized as a serious hazard since the 1970s. Studies by Connor and McDiarmid (2006) and Sessink *et al.* (2011) demonstrated measurable contamination of workplace surfaces and biological samples, linking exposure to mutagenic and reproductive risks. Despite guidelines issued by agencies such as the National Institute for Occupational Safety and Health and the Occupational Safety and Health Administration, implementation gaps remain, particularly in low- and middle-income countries. The significant knowledge gain observed in this study suggests that structured education can help bridge these gaps, even in settings facing resource constraints. Supporting this view, Hon *et al.* (2015) demonstrated a reduction in contamination levels following joint nurse-pharmacist safety training, and Sessink *et al.* (2013) confirmed that combining education with closed-system transfer devices significantly reduces environmental contamination.

From a theoretical perspective, the findings align with the Health Belief Model, which proposes that behaviour change is influenced by perceived susceptibility, severity, benefits, and barriers. By increasing awareness of occupational risks and the benefits of preventive measures, the educational program likely enhanced nurses' motivation to adopt safer practices. However, knowledge alone may not guarantee sustained compliance. Studies such as Martin *et al.* (2018) indicate that heavy workload, inadequate staffing, and limited availability of PPE can hinder consistent adherence to safety protocols. Polovich (2021) further emphasized the importance of ongoing reinforcement and periodic updates to maintain long-term compliance. Therefore, while the present study demonstrates short-term effectiveness, institutional commitment, policy enforcement, and interprofessional collaboration remain essential for sustained practice change.

Table 1: Distribution of Competence Levels Regarding Management of Cytotoxic Drugs (*N*=60).

Sl. No.	Competence Level	Pretest *n* (%)	Posttest *n* (%)
1.	Adequate (≥75%)	2 (3.3%)	55 (91.7%)
2.	Moderately Adequate (50-74%)	22 (36.7%)	5 (8.3%)
3.	Inadequate (<50%)	36 (60.0%)	0 (0.0%)

Table 2: Comparison of Pretest and Posttest Competence Scores Using Paired *t*-Test (*N*=60).

Sl. No.	Test	Mean	Median	SD	Mean Difference	*t*-value	*p*-value	Effect Size (Cohen's d)
1.	Pretest	8.62	8	2.97				
2.	Posttest	16.53	17	1.44	7.91	20.684	<0.001***	3.33

Note: ***$p < 0.001$, highly significant. Paired *t*-test applied.

In the Indian context, structured chemotherapy-safety education is not yet universally implemented. The significant post-intervention improvement observed in this study underscores the need to integrate cytotoxic drug safety modules into staff orientation programs and continuing nursing education. Furthermore, the association between prior training and higher knowledge scores supports the second Hypothesis (H_2) and reinforces the importance of repeated educational exposure. The very large effect size observed in this study further supports the substantial impact of structured educational interventions on improving nurses' competence in cytotoxic drug management.

Future research should explore long-term retention of knowledge, behavioural compliance in clinical practice, and the impact of combining education with engineering controls such as closed-system transfer devices. These findings raise important questions: Does improved knowledge translate into measurable reductions in occupational exposure? How can healthcare institutions sustain compliance in resource-limited settings? Addressing these questions will be crucial in advancing safe oncology practice and protecting healthcare professionals from preventable occupational hazards.

STRENGTHS, LIMITATIONS, AND CLINICAL IMPLICATIONS

Strengths

The present study possesses several notable strengths. The use of a validated structured questionnaire with good internal consistency (Cronbach's alpha=0.86) ensured methodological rigor and measurement reliability. The sample size was determined using statistical power analysis, providing adequate power to detect meaningful differences following the intervention. The structured educational program was based on internationally recognized safety guidelines, enhancing its scientific credibility and practical relevance. Furthermore, the study demonstrates strong clinical applicability, as the intervention can be easily integrated into routine hospital training programs. The findings also emphasize the importance of interprofessional collaboration, particularly between nursing and pharmacy departments, in promoting safe cytotoxic drug handling practices.

Limitations

Although the findings demonstrate a significant improvement in nurses' competence following the educational intervention, the pre-experimental one-group pretest-post-test design has inherent methodological limitations. The absence of a control group makes it difficult to completely rule out alternative explanations for the observed improvement, such as testing effects, maturation, or external learning influences. Furthermore, repeated exposure to the same questionnaire during pretest and post-test assessments may have contributed to improved scores. The study was conducted in a single tertiary care institution, which may limit the generalizability of the findings to other healthcare settings. The use of convenience sampling introduces the possibility of selection bias. Additionally, the follow-up period was short, and long-term retention of knowledge was not assessed. Future studies employing quasi-experimental or randomized controlled designs with comparison groups would provide stronger evidence regarding the effectiveness of structured educational interventions in cytotoxic drug management.

Clinical Implications

From a clinical perspective, the findings underscore the necessity of mandatory annual chemotherapy safety training programs for nurses involved in oncology care. Incorporating cytotoxic drug safety modules into nursing orientation programs can ensure early competency development. Strengthening nurse-pharmacist collaboration is essential for reinforcing standardized preparation, administration, and disposal practices. Institutional policies must also emphasize consistent use of personal protective equipment and adherence to hazardous drug handling protocols to foster a sustained culture of occupational safety.

CONCLUSION

The structured educational program markedly improved nurses' competence in cytotoxic drug management. The significant increase in post-test scores demonstrates the effectiveness of nurse-centered training initiatives in promoting the safe handling and administration of cytotoxic drugs. Empowering nurses through periodic training, adequate protective resources, and institutional policy reinforcement is essential to minimize occupational risks and ensure high-quality oncology care. Moreover, this intervention fostered stronger collaboration between nursing and pharmacy professionals, reinforcing a culture of safety and interprofessional teamwork within hospital settings.

ABBREVIATIONS

WHO: World Health Organization; **NIOSH:** National Institute for Occupational Safety and Health; **PPE:** Personal Protective Equipment; **S-CVI:** Scale-Level Content Validity Index; **SPSS:** Statistical Package for the Social Sciences; **SD:** Standard Deviation; **G*Power:** Statistical Power Analysis Program; **α:** Alpha Level of Significance; **Cohen's d:** Cohen's Effect Size Measure; **B.Sc. Nursing:** Bachelor of Science in Nursing; **H_1:** Research Hypothesis One; **H_2:** Research Hypothesis Two; **PPE:** Personal Protective Equipment.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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