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Chemotherapy-Induced Myelosuppression and Anxiety, Depression, and Sleep Quality Among Family Caregivers of Patients With Cancer: A Patient–Caregiver Paired Cohort Study

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Abstract

Objective

To investigate the association between chemotherapy-induced myelosuppression and anxiety, depression, and sleep quality among family caregivers of patients with cancer, and to identify factors associated with these psychological and sleep outcomes.

Methods

A patient–caregiver paired cohort study was conducted. Patient demographic and clinical characteristics were collected before chemotherapy or within 48 h of hospital admission. Complete blood counts were reassessed 7–14 days after completion of chemotherapy. Myelosuppression was determined based on the lowest recorded white blood cell count, hemoglobin level, and platelet count during this observation period. Patient–caregiver pairs were classified into the no-myelosuppression (No-BMS) group or the myelosuppression (BMS) group, and myelosuppression severity was graded from 0 to 4 according to World Health Organization criteria. During the same observation window, family caregivers completed the Hospital Anxiety and Depression Scale (HADS) and the Pittsburgh Sleep Quality Index (PSQI). Between-group comparisons, correlation analyses, and multivariable linear regression analyses were performed to examine the associations between myelosuppression and caregivers' psychological and sleep outcomes.

Results

A total of 634 patient–caregiver pairs were included in the analysis, comprising 279 pairs in the No-BMS group and 355 in the BMS group. The incidence of myelosuppression was 55.99%. Family caregivers in the BMS group had higher HADS anxiety, HADS depression, and PSQI scores than those in the No-BMS group. Linear regression analyses demonstrated that chemotherapy-induced myelosuppression was significantly associated with higher caregiver anxiety, depression, and PSQI scores (all $P < 0.001$). Significant differences in HADS anxiety, HADS depression, and PSQI scores were also observed across different grades of myelosuppression, with all three scores showing an overall upward trend as myelosuppression severity increased. Multivariable analyses further identified several patient- and caregiver-related factors associated with caregivers' psychological and sleep outcomes, including a history of myelosuppression, patient performance status, pathological diagnosis, patient age, caregiver educational level, caregiver sex, and caregiver–patient relationship.

Conclusion

Chemotherapy-induced myelosuppression was associated with greater anxiety and depression and poorer sleep quality among family caregivers of patients with cancer. During the period of increased risk for post-chemotherapy myelosuppression, clinical care should incorporate concurrent assessment of caregivers' psychological well-being and sleep quality, with risk-stratified supportive interventions provided to caregivers at higher risk.

1. Introduction

Chemotherapy remains an essential component of anticancer treatment for many patients with cancer. Chemotherapy-induced myelosuppression is a common and clinically significant adverse effect of treatment [1–3], characterized primarily by reductions in leukocyte or neutrophil counts, hemoglobin levels, and platelet counts. These hematologic toxicities may increase the risks of infection, bleeding, blood transfusion, treatment delays, and chemotherapy dose modifications [4–6]. Recent real-world studies have demonstrated a substantial burden of chemotherapy-induced myelosuppression. In patients with extensive-stage small-cell lung cancer, myelosuppressive events occur frequently following chemotherapy, and grade ≥ 3 single-lineage or multilineage myelosuppression is not uncommon [2, 3]. For patients, the development of myelosuppression therefore represents not only increased clinical risk but also greater and more complex care needs.

In the Chinese healthcare context, family members often serve as the primary caregivers for patients with cancer throughout treatment. When myelosuppression develops, caregivers may assume additional responsibilities, including monitoring for fever, infection, and bleeding; ensuring timely follow-up complete blood counts; recognizing abnormal symptoms; and communicating with healthcare professionals. Meanwhile, psychological distress is common among family caregivers of patients with cancer, and caregiving burden, patient symptoms, and caregiving-related stress may adversely affect their anxiety, depression, and sleep [7–9]. Recent evidence indicates that the prevalence of moderate-to-severe anxiety and severe depression among family caregivers of patients with cancer may reach 53.0% and 46.3%, respectively [7]. Our previous research also found that when patients experienced acute chemotherapy-induced nausea and vomiting, the prevalence of anxiety and depression among their family caregivers increased to 42.0% and 43.3%, respectively [10]. Moreover, caregiver anxiety and depression scores decreased significantly following effective control of acute chemotherapy-related hiccups [11]. Collectively, these findings suggest that treatment-related symptoms and adverse effects experienced by patients may have broader psychological implications for their family caregivers.

Therefore, using paired patient–caregiver data, this study aimed to explore the association between chemotherapy-induced myelosuppression and anxiety, depression, and sleep quality among family caregivers and to further identify factors associated with these outcomes. The findings may provide evidence to inform symptom management for patients undergoing chemotherapy and the development of supportive interventions for their family caregivers.

2. Materials and Methods

2.1 Study Design and Participants

This patient–caregiver paired cohort study included patients with cancer undergoing chemotherapy and their family caregivers who were hospitalized at the Oncology Center of West China Shangjin Hospital between May 2025 and May 2026. Based on whether chemotherapy-induced myelosuppression occurred, patient–caregiver pairs were classified into the no-myelosuppression (No-BMS) group and the myelosuppression (BMS) group.

Patients were eligible for inclusion if they: (1) voluntarily agreed to participate in the study; (2) had a pathologically confirmed malignant tumor; (3) had adequate communication abilities and were able to cooperate with study assessments; (4) received chemotherapy during the current hospitalization, either alone or in combination with immunotherapy, targeted therapy, antiangiogenic therapy, or radiotherapy; (5) underwent a peripheral complete blood count 7–14 days after chemotherapy; and (6) had undergone a peripheral complete blood count within 1 week before enrollment, with white blood cell count, hemoglobin level, and platelet count not meeting the World Health Organization (WHO) criteria for any grade of myelosuppression.

Patients were excluded if they: (1) withdrew from the study or declined further participation during data collection; or (2) had cognitive or psychiatric disorders that prevented them from completing the questionnaires or cooperating with study assessments.

Family caregivers were eligible for inclusion if they: (1) were the patient's primary family caregiver during the current course of treatment; (2) were able to complete the questionnaires independently or with guidance from the researchers; (3) were aware of the patient's medical condition and provided written informed consent; and (4) had HADS-A and HADS-D scores of 0–7 at baseline, indicating no anxiety or depression.

Family caregivers were excluded if they: (1) declined participation or withdrew during the study; (2) were no longer the patient's primary caregiver during the study period; (3) had cognitive or psychiatric disorders; (4) had a known serious conflict with the patient; (5) were professional or paid caregivers; or (6) had a serious physical illness, malignant tumor, or other condition that could substantially affect psychological or sleep outcomes.

2.2 Study Instruments

2.2.1 General Information Questionnaire

Patient characteristics collected using the general information questionnaire included sex, age, body mass index (BMI), marital status, educational level, type of medical insurance, employment status, place of residence, whether the patient was receiving initial treatment, smoking history, alcohol consumption history, family history of cancer, comorbidities, pathological diagnosis, tumor–node–metastasis (TNM)

stage, duration of chemotherapy, performance status (PS), and history of myelosuppression. Caregiver characteristics included relationship to the patient, educational level, sex, age, and employment status.

2.2.2 Hospital Anxiety and Depression Scale (HADS)

The HADS was used to assess anxiety and depression among family caregivers. The scale consists of 14 items divided into two seven-item subscales assessing anxiety (HADS-A) and depression (HADS-D). Each item is scored from 0 to 3, yielding a score of 0–21 for each subscale. Scores of 0–7 indicate no anxiety or depression, 8–10 mild anxiety or depression, 11–14 moderate anxiety or depression, and 15–21 severe anxiety or depression. Recent studies involving patients with cancer and their caregivers have demonstrated satisfactory psychometric properties of the HADS, supporting its use for assessing anxiety and depression in these populations [12, 13].

2.2.3 Pittsburgh Sleep Quality Index (PSQI)

The PSQI was used to assess family caregivers' sleep quality over the preceding month. It comprises 19 self-rated items and 5 items rated by a bed partner or roommate, with 18 self-rated items contributing to the total score. These items are grouped into seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component is scored from 0 to 3, yielding a global score ranging from 0 to 21, with higher scores indicating poorer sleep quality. Recent studies have supported the utility of the PSQI for assessing sleep quality among informal caregivers and patients with cancer [14, 15]. In the present study, the scale demonstrated good internal consistency, with a Cronbach's α coefficient of 0.845.

2.2.4 Assessment of Myelosuppression

Myelosuppression was assessed during a predefined window of 7–14 days after completion of chemotherapy. This assessment window was selected based on the expected decline in peripheral blood cell counts following cytotoxic chemotherapy and the typical timing of the neutrophil nadir. Recent supportive care guidelines and consensus recommendations indicate that, in many patients, the neutrophil nadir may occur 7–14 days after chemotherapy and that the assessment and management of hematologic toxicity should take into account the myelosuppressive risk of the chemotherapy regimen, individual patient characteristics, and dynamic changes in complete blood counts [16–18]. Therefore, assessment of white blood cell (WBC) count, hemoglobin (Hb) level, and platelet (PLT) count during this period was considered appropriate for characterizing chemotherapy-induced myelosuppression within the treatment cycle.

The severity of myelosuppression was graded from 0 to 4 according to the World Health Organization criteria: grade 0, WBC ≥ 4.0 × 10^9/L, Hb ≥ 110 g/L, and PLT ≥ 100 × 10^9/L;grade 1, WBC 3.0–3.9 × 10^9/L, Hb 95–100 g/L, or PLT 75–99 × 10^9/L□grade 2, WBC 2.0–2.9 × 10^9/L, Hb 80–94 g/L, or PLT 50–74 × 10^9/L□grade 3, WBC 1.0–1.9 × 10^9/L, Hb 65–79 g/L, or PLT 25–49 × 10^9/L□and grade 4, WBC < 1.0 × 10^9/L, Hb < 65 g/L, or PLT < 25 × 10^9/L. When multiple complete blood count results were available for

the same patient within the observation window, the most severe grade identified across the WBC, Hb, and PLT parameters was used to define the overall myelosuppression grade for that chemotherapy cycle.

2.3 Study Procedures and Quality Control

Before chemotherapy or within 48 h of hospital admission, the researchers used standardized instructions to explain the study objectives, questionnaire completion procedures, and relevant precautions to the patients and their family caregivers. After written informed consent was obtained, both patients and family caregivers completed the general information questionnaire. Questionnaires were completed independently whenever possible. If participants had difficulty understanding an item, the researchers provided clarification using standardized explanations without guiding or influencing their responses. Upon completion, all questionnaires were reviewed on site for completeness and logical consistency, and any missing items were addressed promptly.

Myelosuppression was assessed 7–14 days after completion of chemotherapy. During the same observation window, family caregivers completed the HADS and PSQI assessments. After data collection, all records were reviewed again for completeness, and patient–caregiver pairs with missing data on key outcome variables were excluded from the analysis. Based on the occurrence and severity of myelosuppression, patient–caregiver pairs were categorized into the No-BMS group (grade 0) or the BMS group (grades 1–4). The study flow is presented in Fig. 1.

2.4 Statistical Analysis

Statistical analyses were performed using SPSS version 27.0. Continuous variables were assessed for normality. Normally distributed variables are presented as the mean ± standard deviation (SD) or mean ± standard error (SE), as appropriate, and were compared between groups using the independent-samples *t* test. Non-normally distributed variables are presented as the median and interquartile range (IQR) and were compared using the Mann–Whitney *U* test or Kruskal–Wallis *H* test, as appropriate. Categorical variables are presented as frequencies and percentages and were compared using the χ^2 test or Fisher's exact test.Linear regression analysis was used to examine the associations between chemotherapy-induced myelosuppression and caregiver anxiety, depression, and sleep quality. Multivariable linear regression analyses were subsequently performed to identify factors associated with these caregiver outcomes. All statistical tests were two-sided, and a $P < 0.05$ was considered statistically significant.

3. Results

3.1 Participant Characteristics

A total of 958 patient–caregiver pairs were screened. Of these, 282 pairs were excluded because they did not meet the eligibility criteria, declined participation, or had incomplete data, leaving 676 pairs enrolled in the study. During follow-up, 42 pairs were lost to follow-up or withdrew from the study, resulting in 634 patient–caregiver pairs included in the final analysis. Of these, 279 pairs were classified

into the No-BMS group and 355 into the BMS group, corresponding to an incidence of chemotherapy-induced myelosuppression of 55.99%.

No statistically significant differences were observed between the No-BMS and BMS groups in patient sex, age, body mass index (BMI), type of medical insurance, initial treatment status, smoking history, alcohol consumption history, family history of cancer, comorbidities, pathological diagnosis, TNM stage, marital status, educational level, employment status, place of residence, or duration of chemotherapy (all $P > 0.05$; Table 1). Similarly, the two groups did not differ significantly in caregiver–patient relationship, caregiver educational level, sex, age, or employment status (all $P > 0.05$; Table 2).

Table 1
General demographic characteristics of patients

		No-BMS(n = 279)	BMS(n = 355)	t/Z/ χ^2	P
Gender	male	158	198	0.047	0.829
	female	121	157		
Age		58.08 ± 0.70	57.98 ± 0.76	1.702	0.089
BMI(kg/m^2)	<18.5	28	35	0.359	0.949
	18.5 ~ 24.0	159	210		
	24.0 ~ 28	77	91		
	≥ 28	15	19		
Marital status	yes	14	23	0.607	0.436
	no	265	332		
Educational level	Primary school or below	61	86	0.583	0.900
	Junior high school or high school	139	168		
	Junior college	52	67		
	Bachelor's degree, postgraduate degree or above	27	34		
Insurance type	Employee-based basic medical insurance	15	14	0.744	0.689
	Resident- based basic medical insurance	167	217		
	Other insurance or self-pay	97	124		
Employment status	Employed	67	76	2.448	0.294
	Unemployed	85	129		
	Retired	127	150		
Place of residence	Urban area	208	272	0.363	0.547
	Rural area	71	83		

Note: The No-BMS included patients without bone marrow suppression, and the BMS included patients with bone marrow suppression.

		No-BMS(n = 279)	BMS(n = 355)	t/Z/ χ^2	P
Initial treatment status	no	262	327	0.763	0.383
	yes	17	28		
Smoking history	no	177	203	2.548	0.110
	yes	102	152		
Alcohol consumption history	no	170	223	0.236	0.627
	yes	109	132		
Family history of cancer	no	251	306	2.078	0.149
	yes	28	49		
Presence of comorbid chronic diseases	no	189	254	1.076	0.300
	yes	90	101		
Pathological diagnosis	Lung cancer	68	72	1.968	0.579
	Colorectal cancer	79	98		
	Breast cancer,other digestive system neoplasms	42	57		
	others	90	128		
TNM staging	Stage I	15	21	0.278	0.964
	Stage II	13	16		
	Stage III	76	91		
	Stage IV	175	227		
PS Score	0	253	308	1.533	0.125
	1	20	36		
	2	6	11		
	3	0	0		
	4	0	0		
	5	0	0		

Note: The No-BMS included patients without bone marrow suppression, and the BMS included patients with bone marrow suppression.

		No-BMS(n = 279)	BMS(n = 355)	t/Z/ χ^2	P
Prior myelosuppression	0	275	347	0.565	0.452
	1	4	8		
Duration of chemotherapy		2.50 ± 0.13	2.49 ± 0.09	1.142	0.254
Note: The No-BMS included patients without bone marrow suppression, and the BMS included patients with bone marrow suppression.					

Table 2
General demographic characteristics of Family caregivers

		No-BMS(n = 279)	BMS(n = 355)	t/Z/χ^2	P
Relationship between familty caregivers and patients	Spouse	125	150	-0.55	0.585
	Immediate family member	142	191		
	Collateral relative	4	6		
	Non-blood-related individual	8	8		
Educational level	Primary school or below	28	28	-0.651	0.515
	Junior high school or high school	99	113		
	Junior college	72	123		
	Bachelor's degree, postgraduate degree or above	80	91		
Gender	male	122	174	1.754	0.185
	female	157	181		
Age		46.97 ± 0.75	45.85 ± 0.69	1.09	0.276
Employment status	Employed	185	236	2.313	0.315
	Unemployed	42	41		
	Retired	52	78		

3.2 Overall Association Between Myelosuppression and Caregiver Anxiety, Depression, and Sleep Quality

The mean HADS anxiety, HADS depression, and PSQI scores among family caregivers in the No-BMS group were 3.84 ± 0.12, 3.53 ± 0.14, and 5.69 ± 0.17, respectively, compared with 4.68 ± 0.11, 3.82 ± 0.13, and 6.21 ± 0.15, respectively, in the BMS group.

Linear regression analyses showed that chemotherapy-induced myelosuppression was significantly associated with higher HADS anxiety, HADS depression, and PSQI scores among family caregivers, with regression coefficients (*B*) of 0.4671 (95% CI, 0.3139–0.6203), 0.3659 (95% CI, 0.1918–0.5400), and 0.4468 (95% CI, 0.2402–0.6534), respectively (all $P < 0.001$). The standardized regression coefficient was highest for anxiety (β = 0.2317), followed by PSQI score (β = 0.1666) and depression (β = 0.1620) (Table 3).

Table 3
Impact of Myelosuppression in Cancer Patients on Anxiety, Depression, and Sleep Disturbance Among Family Caregivers

Anxiety score of family caregivers	**B**	**SE(B)**	**Beta**	**t**	**P**	**95%CI(B)**
	0.4671	**0.0780**	**0.2317**	**5.9881**	**< 0.001**	**(0.3139,0.6203)**
Depression score of family caregivers	0.3659	0.0887	0.1620	4.1268	< 0.001	(0.1918,0.5400)
Pittsburgh Sleep Quality Index (PSQI) scores among family caregivers	0.4468	0.1052	0.1666	4.2466	< 0.001	(0.2402,0.6534)

3.3 Comparison of Anxiety, Depression, and Sleep Quality Among Family Caregivers Across Myelosuppression Grades

HADS anxiety, HADS depression, and PSQI scores among family caregivers differed significantly across the five grades of myelosuppression. From grades 0 to 4, caregiver HADS anxiety scores were 3.84 ± 0.12, 4.47 ± 0.13, 4.78 ± 0.22, 4.85 ± 0.32, and 6.24 ± 0.94, respectively ($F = 9.880$, $P < 0.001$). The corresponding HADS depression scores were 3.53 ± 0.14, 3.41 ± 0.16, 4.05 ± 0.24, 4.77 ± 0.33, and 5.35 ± 0.67, respectively ($F = 6.060$, $P < 0.001$), while PSQI scores were 5.69 ± 0.17, 5.81 ± 0.19, 6.58 ± 0.30, 6.46 ± 0.40, and 8.47 ± 0.69, respectively ($F = 5.960$, $P < 0.001$). Overall, all three caregiver outcomes tended to increase with increasing severity of myelosuppression (Table 4).

Table 4
Effects of Different Grades of Myelosuppression in Patients and family Caregivers

Anxiety score of family caregivers	**Grade 0**	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**	**F**	**P**
	3.84 ± 0.12	**4.47 ± 0.13**	**4.78 ± 0.22**	**4.85 ± 0.32**	**6.24 ± 0.94**	**9.880**	**< 0.001**
Depression score of family caregivers	3.53 ± 0.14	3.41 ± 0.16	4.05 ± 0.24	4.77 ± 0.33	5.35 ± 0.67	6.060	< 0.001
Pittsburgh Sleep Quality Index (PSQI) score of family caregivers	5.69 ± 0.17	5.81 ± 0.19	6.58 ± 0.30	6.46 ± 0.40	8.47 ± 0.69	5.960	< 0.001
Overall fatigue severity	2.56 ± 0.10	2.76 ± 0.11	3.66 ± 0.17	4.85 ± 0.25	6.20 ± 0.41	36.850	< 0.001
Overall fatigue interference	1.54 ± 0.08	1.80 ± 0.09	2.49 ± 0.12	2.87 ± 0.25	4.58 ± 0.57	34.100	< 0.001
Anxiety score of patients	4.85 ± 0.15	5.53 ± 0.14	6.20 ± 0.21	6.82 ± 0.29	9.06 ± 0.82	21.940	< 0.001
Depression score of patients	4.36 ± 0.18	4.41 ± 0.19	5.22 ± 0.27	6.44 ± 0.32	7.41 ± 0.97	9.830	< 0.001
Pittsburgh Sleep Quality Index (PSQI) score of patients	6.91 ± 0.22	7.28 ± 0.23	8.40 ± 0.33	9.69 ± 0.49	12.82 ± 0.61	18.170	< 0.001

3.4 Multivariable Analysis of Factors Associated With Anxiety, Depression, and Sleep Quality Among Family Caregivers

3.4.1 Factors Associated With Anxiety Among Family Caregivers

Multivariable linear regression analysis showed that caregiver–patient relationship (*B* = − 0.5801, 95% CI, − 0.8269 to − 0.3333; *P* < 0.001), caregiver educational level (*B* = − 0.3308, 95% CI, − 0.4994 to − 0.1622; *P* < 0.001), and patient marital status (*B* = − 0.7074, 95% CI, − 1.3716 to − 0.0432; *P* = 0.037) had negative regression coefficients. A history of myelosuppression in the patient (*B* = 0.7566, 95% CI, 0.4405–1.0727; *P* < 0.001), patient pathological diagnosis (*B* = 0.1893, 95% CI, 0.0523–0.3264; *P* = 0.007), and caregiver sex (*B* = 0.3336, 95% CI, 0.0249–0.6423; *P* = 0.033) were also significantly associated with caregiver anxiety scores (Table 5).

Table 5
Multivariable Linear Regression Analysis of Factors Associated With Anxiety Among Family Caregivers

(Constant)	B	SE(B)	Beta	t	P	95%CI(B)
	5.4411	**0.5596**	**—**	**9.7233**	**< 0.001**	**(4.3422,6.5400)**
Relationship with patients	-0.5801	0.1257	-0.1793	-4.6162	< 0.001	(-0.8269,-0.3333)
Previous myelosuppression history of patients	0.7566	0.1610	0.1803	4.7002	< 0.001	(0.4405,1.0727)
Educational level of family caregivers	-0.3308	0.0859	-0.1503	-3.8523	< 0.001	(-0.4994,-0.1622)
Pathological diagnosis of patients	0.1893	0.0698	0.1058	2.7132	0.007	(0.0523,0.3264)
Gender of family caregivers	0.3336	0.1572	0.0797	2.1219	0.033	(0.0249,0.6423)
Patients marital status	-0.7074	0.3382	-0.0795	-2.0916	0.037	(-1.3716,-0.0432)

3.4.2 Factors Associated With Depression Among Family Caregivers

Multivariable linear regression analysis showed that caregiver educational level (*B* = − 0.5026, 95% CI, − 0.6942 to − 0.3109; *P* < 0.001), patient PS score (*B* = 0.6848, 95% CI, 0.3240 to − 1.0456; *P* = 0.001), caregiver–patient relationship (*B* = − 0.3959, 95% CI, − 0.6755 to − 0.1164; *P* = 0.004), and caregiver sex (*B* = 0.5035, 95% CI, 0.1458 to − 0.8612; *P* = 0.023) were significantly associated with caregiver depression scores. Among these variables, caregiver educational level showed the largest absolute standardized regression coefficient (|β| = 0.2039), indicating a relatively stronger association with depression scores (Table 6).

Table 6
Multivariable Linear Regression Analysis of Factors Associated With Depression Among Family Caregivers

(Constant)	B	SE(B)	Beta	t	P	95%CI(B)
	5.0698	**0.4417**	**—**	**11.4781**	**< 0.001**	**(4.2024,5.9371)**
Educational level of family caregivers	-0.5026	0.0976	-0.2039	-5.1484	< 0.001	(-0.6942,-0.3109)
Performance Status (PS) score of patients	0.6848	0.1838	0.1411	3.7268	0.001	(0.3240,1.0456)
Relationship with patients	-0.3959	0.1424	-0.1092	-2.7810	0.004	(-0.6755,-0.1164)
Gender of falimy caregivers	0.5035	0.1821	0.1074	2.7642	0.023	(0.1458,0.8612)

3.4.3 Factors Associated With Sleep Quality Among Family Caregivers

Multivariable linear regression analysis of caregiver PSQI scores showed that caregiver educational level (*B* = − 0.6027, 95% CI, − 0.8312 to − 0.3743; *P* < 0.001) and caregiver–patient relationship (*B* = − 0.4378, 95% CI, − 0.7739 to − 0.1017; *P* = 0.011) had negative regression coefficients. In contrast, caregiver sex (*B* = 0.6078, 95% CI, 0.1908–1.0249; *P* = 0.004), patient history of myelosuppression (*B* = 0.5350, 95% CI, 0.1187–0.9414; *P* = 0.012), and patient age (*B* = 0.0188, 95% CI, 0.0029–0.0347; *P* = 0.021) had positive regression coefficients. Among these variables, caregiver educational level had the largest absolute standardized regression coefficient (|β| = 0.2059), indicating the strongest relative association with caregiver PSQI scores (Table 7).

Table 7
Multivariable Linear Regression Analysis of Factors Associated With Sleep Quality Among Family Caregivers

(Constant)	B	SE(B)	Beta	t	P	95%CI(B)
	5.9615	**0.7521**	**—**	**7.9268**	**< 0.001**	**(4.4846,7.4384)**
Educational level of family caregivers	-0.6027	0.1163	-0.2059	-5.1814	< 0.001	(-0.8312,-0.3743)
Gender of family caregivers	0.6078	0.2124	0.1092	2.8621	0.004	(0.1908,1.0249)
Previous myelosuppression history of patients	0.5350	0.2120	0.0958	2.5234	0.012	(0.1187,0.9414)
Caregiver–patient relationship	-0.4378	0.1712	-0.1017	-2.5579	0.011	(-0.7739,-0.1017)
Age of patients	0.0188	0.0081	0.0895	2.3223	0.021	(0.0029,0.0347)

4. Discussion

4.1 High Incidence of Chemotherapy-Induced Myelosuppression Highlights the Need for Clinical Attention

In the present study, the incidence of chemotherapy-induced myelosuppression among hospitalized patients with cancer was 55.99%, indicating that myelosuppression is common during chemotherapy. Previous real-world studies have similarly demonstrated a substantial clinical burden associated with chemotherapy-induced myelosuppression, including increased risks of infection and bleeding, greater need for blood transfusion, treatment delays, chemotherapy dose modifications, and impaired quality of life [4–6]. Rather than focusing solely on hematologic abnormalities in patients, the present study linked chemotherapy-induced hematologic toxicity with psychological and sleep outcomes among family caregivers. These findings suggest that myelosuppression should be considered not only a treatment-related complication experienced by patients but also an event that may have broader implications for the patient–caregiver dyad.

Myelosuppression was assessed within 7–14 days after completion of chemotherapy, a period that more closely corresponds to the expected nadir of peripheral blood cell counts following many chemotherapy regimens [16–18]. This predefined assessment window may improve the temporal accuracy of identifying chemotherapy-induced myelosuppression and provides greater temporal alignment between hematologic changes in patients and concurrent psychological and sleep outcomes among their family caregivers.

4.2 Chemotherapy-Induced Myelosuppression Is Associated With Greater Anxiety and Depression and Poorer Sleep Quality Among Family Caregivers

In the present study, family caregivers in the BMS group had higher HADS anxiety, HADS depression, and PSQI scores than those in the No-BMS group. Regression analyses further demonstrated that chemotherapy-induced myelosuppression was significantly associated with higher scores for all three outcomes. These findings suggest that myelosuppression may have implications beyond treatment-related toxicity in patients and may also be associated with the psychological well-being and sleep of their family caregivers. Potential explanations include increased caregiving demands, heightened vigilance for complications, and greater uncertainty regarding treatment and recovery.

These findings are consistent with previous studies showing that treatment-related symptoms and adverse effects experienced by patients with cancer are associated with psychological outcomes among their family caregivers. Luo et al. [10] reported that when patients experienced acute chemotherapy-induced nausea and vomiting (CINV), the prevalence of anxiety and depression among family caregivers was 42.0% and 43.3%, respectively, suggesting substantial psychological distress among caregivers during acute treatment-related adverse events. Similarly, the longitudinal study by Litzelman et al. [9] showed that patient symptoms, caregiving burden, and caregiving-related stress predicted subsequent psychoneurological symptoms among cancer caregivers. More recently, a study of acute chemotherapy-related hiccups found that, among caregivers of affected patients, anxiety and depression scores were significantly lower following a behavioral–physical intervention than with usual care (3.91 vs. 8.31 and 4.30 vs. 8.90, respectively) [11]. Recent studies on the incidence, symptom experience, and nonpharmacological management of chemotherapy-related hiccups have also suggested that, although hiccups are often underestimated [19–21], they may interfere with patients' sleep, eating, communication, and overall treatment experience and may have broader implications for caregiver psychological responses [22–24].

Unlike subjective treatment-related symptoms such as nausea, vomiting, hiccups, and pain [25, 26], myelosuppression is characterized by a combination of abnormal hematologic findings, potential complications, and the need for continued monitoring outside the hospital. Family caregivers may therefore remain highly vigilant because they are often required to monitor for fever, infection, and bleeding and to facilitate follow-up complete blood counts. Incorporating family caregivers into the management of chemotherapy-induced myelosuppression may therefore broaden the scope of supportive care beyond the patient alone and facilitate a more dyadic approach to treatment-related toxicity management [27–29].

Notably, the standardized regression coefficient for the association between myelosuppression and caregiver anxiety was larger than those for depression and PSQI scores, suggesting that anxiety may be a particularly sensitive psychological response to myelosuppression. Compared with depression, anxiety may more closely reflect caregivers' immediate concerns and uncertainty when confronted with acute treatment-related risks [30–32]. Accordingly, when educating patients and families about the risk of

myelosuppression, clinical nurses should provide not only information about potential complications but also clear and actionable guidance on how to recognize and respond to warning signs. Such guidance may help reduce persistent uncertainty and tension arising from caregivers' lack of confidence in identifying and managing abnormal symptoms [33, 34].

4.3 Myelosuppression Grade May Help Identify Family Caregivers at Higher Risk of Psychological Distress and Poor Sleep Quality

The present study further examined caregiver outcomes across different grades of myelosuppression. HADS anxiety, HADS depression, and PSQI scores differed significantly across grades 0–4 and showed an overall tendency to increase with increasing severity of myelosuppression, with the highest scores observed among caregivers of patients with grade 4 myelosuppression. These findings suggest that, in addition to its clinical relevance for risk stratification in patients, the severity of myelosuppression may also provide a useful indicator for identifying family caregivers at higher risk of psychological distress and poor sleep quality [35, 36].

From a nursing management perspective, myelosuppression grade may also inform the intensity of supportive interventions provided to family caregivers. For caregivers of patients with grade 1–2 myelosuppression, support may focus primarily on health education and guidance regarding symptom monitoring and self-management. For those caring for patients with grade 3–4 myelosuppression, in addition to enhanced education regarding the warning signs of infection and bleeding, healthcare professionals should proactively assess caregivers for anxiety, depression, and sleep problems. When indicated, psychological support, practical strategies for nighttime caregiving, and clear pathways for follow-up and communication with healthcare professionals may be provided to reduce psychological and sleep-related burden among caregivers [37, 38].

4.4 Psychological and Sleep Outcomes Among Family Caregivers Are Associated With Both Patient- and Caregiver-Related Factors

Multivariable analyses showed that anxiety, depression, and sleep quality among family caregivers were associated with both patient-related factors, including a history of myelosuppression, PS score, pathological diagnosis, and patient age, and caregiver-related factors, including sex, educational level, and caregiver–patient relationship. These findings suggest that caregivers' psychological well-being and sleep are unlikely to be associated with a single clinical event alone but may reflect the interplay of patients' disease-related characteristics, treatment toxicity, caregiving relationships, and caregivers' individual resources. Previous studies have similarly indicated that patient symptom burden, caregiving burden, health literacy, caregiver–patient relationships, and family resources are associated with psychological well-being and quality of life among family caregivers of patients with cancer [7–9, 35–38].

Notably, caregiver educational level was significantly associated with anxiety, depression, and PSQI scores across all three multivariable models, suggesting that caregivers with different educational backgrounds may differ in their understanding of complete blood count results, perceived risks of myelosuppression, and ability to respond to home-monitoring requirements. Accordingly, clinical education should move beyond a one-size-fits-all approach and be tailored to caregivers' educational background, health literacy, and practical caregiving capacity. Strategies such as illustrated educational materials, risk checklists, follow-up testing schedules, and step-by-step guidance for responding to warning signs may help translate complex medical information into practical and actionable caregiving tasks [27–29].

4.5 Clinical Implications

The findings of this study support extending the management of chemotherapy-induced myelosuppression beyond the monitoring of patients' hematologic parameters toward a more dyadic approach that considers both patients and their family caregivers. The period 7–14 days after chemotherapy may provide a practical window for reassessing complete blood counts while concurrently screening family caregivers for psychological distress and sleep problems [16–18]. Family caregivers of patients with a history of myelosuppression, higher PS scores, or moderate-to-severe myelosuppression may warrant particular attention and additional supportive care [32–35].

Potential nursing interventions may include: (1) educating caregivers about the expected timing of myelosuppression, warning signs, and appropriate responses; (2) providing concise checklists to facilitate recognition of warning signs such as fever and bleeding; (3) clearly specifying the timing of follow-up complete blood counts and indications for seeking medical attention; (4) providing psychological support and referral when appropriate for caregivers with elevated anxiety, depression, or PSQI scores; and (5) developing symptom-management education that actively involves both patients and family caregivers. Recent systematic reviews and randomized controlled trials suggest that psychoeducational, eHealth, cognitive behavioral, and patient–caregiver dyadic interventions may help reduce caregiver burden and psychological distress and improve quality of life [36–38].

4.6 Limitations

This study has several limitations. First, this was a single-center study involving hospitalized patients receiving chemotherapy and their family caregivers, which may have introduced selection bias. Therefore, caution is warranted when generalizing the findings to other geographic regions, outpatient chemotherapy settings, or populations with different types of cancer. Second, caregiver anxiety, depression, and sleep quality were assessed primarily using self-reported questionnaires and may therefore have been subject to self-report bias. Third, the study assessed myelosuppression during a single chemotherapy cycle and within a predefined window of 7–14 days after chemotherapy. It did not longitudinally capture the full course of myelosuppression, including its onset, clinical management, and recovery, nor did it assess changes in caregivers' psychological and sleep outcomes after patients recovered from myelosuppression. Fourth, family caregivers with anxiety or depression at baseline were

not included in the study. Although this criterion allowed the analysis to focus on psychological symptoms emerging during the observation period, it may limit the generalizability of the findings to caregivers with pre-existing psychological distress. Future studies should incorporate longitudinal assessments at multiple time points, include caregivers with a broader range of baseline psychological states, and consider stratified analyses according to chemotherapy regimen, drug class, and treatment cycle to better characterize the longitudinal associations between changes in myelosuppression and psychological and sleep outcomes among family caregivers.

5. Conclusion

Chemotherapy-induced myelosuppression in patients with cancer was associated with greater anxiety and depression and poorer sleep quality among family caregivers, with the overall psychological and sleep burden tending to increase with increasing severity of myelosuppression. During the period of increased risk for post-chemotherapy myelosuppression, clinical care should incorporate concurrent assessment of caregivers' psychological well-being and sleep quality and integrate family caregivers into risk-stratified supportive care and symptom-management pathways.

Declarations

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Compliance with Ethical Standards

This study was conducted in accordance with the Declaration of Helsinki and the International Ethical Guidelines for Health-related Research Involving Humans. The study protocol was approved by the Biomedical Ethics Review Committee of West China Hospital, Sichuan University (approval No. 2025 Review (181)). The study was registered with the Chinese Clinical Trial Registry (ChiCTR) on May 7, 2025 (registration No. ChiCTR2500102051).

Author Contribution

XZL: data curation, formal analysis, investigation, visualization, original draft; YHZ: data curation, formal analysis; LLY: formal analysis, resources, software; JC: resources, validation; JX: resources, validation;JRL: resources, validation; XY: resources, validation; JW: resources, validation;LLX resources, project administration, supervision, review and editing, conceptualization; JZ: conceptualization, project administration, resources, supervision, review and editing.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to participant privacy and ethical considerations but are available from the corresponding author on reasonable request.

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Figures

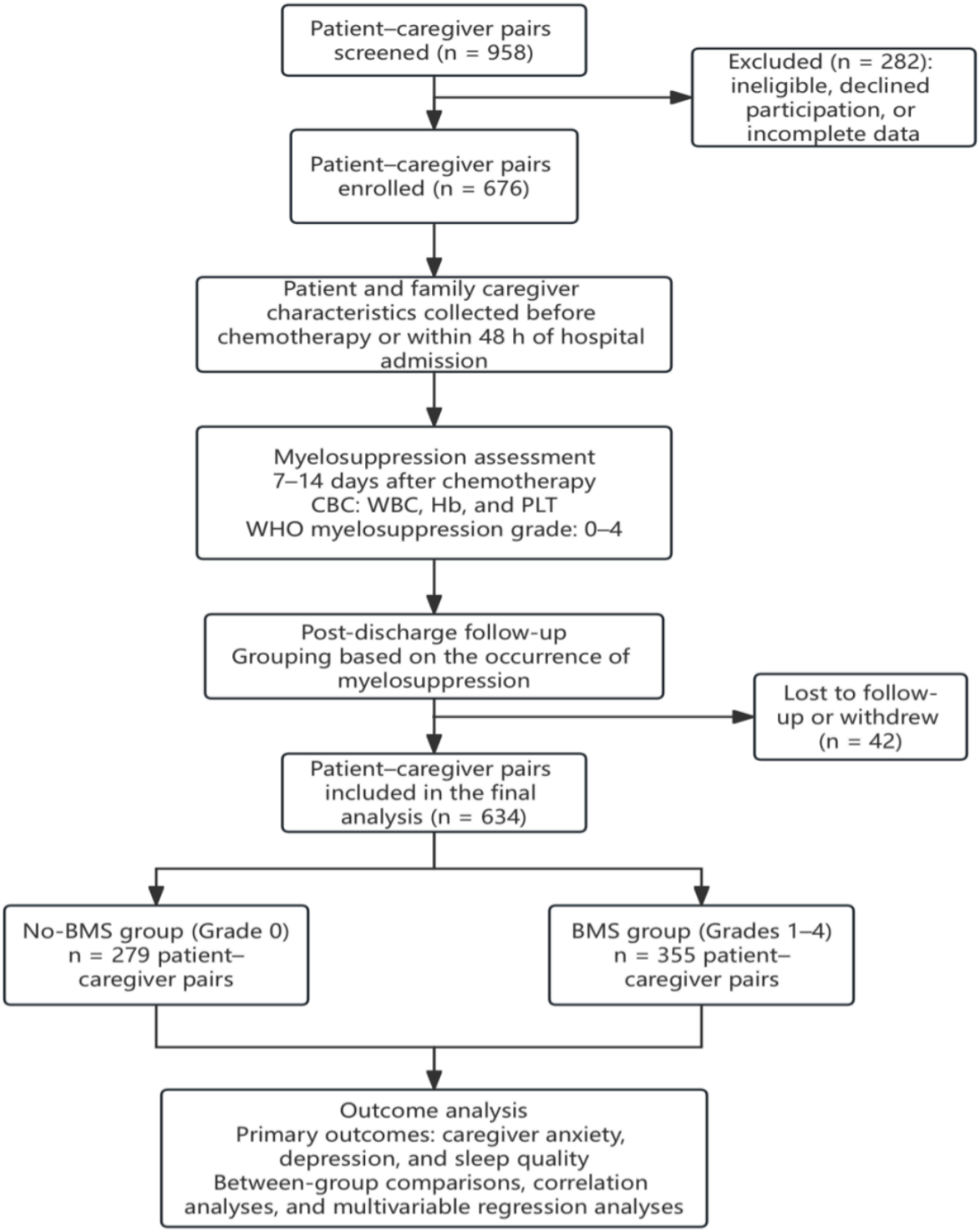


Figure 1

Flowchart of the patient–caregiver paired cohort study