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Electrocardiographic changes and their impact on psychological distress and sleep quality in breast cancer patients during anthracycline-based chemotherapy

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Abstract: Background: Breast cancer is the most common malignant tumor in women. Anthracycline is an essential adjuvant chemotherapy drug. Due to its cardiotoxicity, anthracyclines may lead to abnormal electrocardiogram, which may induce anxiety, depression and sleep disorders. Current studies mainly focus on the changes of echocardiogram parameters and serum myocardial markers, and the dynamic evolution of electrocardiogram. However, the mechanism of its interaction with psycho-sleep are still unclear. **Objective:** To analyze the electrocardiogram results of breast cancer patients with anthracycline chemotherapy, and to analyze its correlation with psychological disorders and sleep quality. **Methods:** In this longitudinal observational study, 100 breast cancer patients receiving anthracycline-based chemotherapy underwent 12-lead electrocardiogram (ECG) monitoring at three time points: within 7 days before chemotherapy initiation (T0), 24 hours after the completion of the second chemotherapy cycle (T1), and 24 hours after the completion of the fourth cycle (T2). QTc intervals and ST-segment changes were recorded. Concurrent psychological and sleep status assessments were performed using the Hospital Anxiety and Depression Scale (HADS) and the Pittsburgh Sleep Quality Index (PSQI). **Results:** After the fourth cycle of chemotherapy (T2), 36 patients had abnormal electrocardiogram (ECG), and the overall abnormal rate increased from 3% to 36.0%, mainly manifested as QTc prolongation (16.0%), ST segment depression (11.0%) and T wave changes (17.0%). Patients with age ≥ 50 , BMI $\geq 24\text{kg/m}^2$, postmenopausal, TNM stage III, cumulative drug dose $\geq 300\text{ mg/m}^2$, hypertension, hyperlipidemia and other characteristics have a higher probability of abnormal ECG after chemotherapy. Psychological assessment showed that HADS-A and HADS-D scores increased from 5.71 ± 2.24 and 5.06 ± 1.73 at T0 to 9.74 ± 3.11 and 9.15 ± 2.80 at T2, respectively ($P < 0.001$). The incidence of anxiety increased from 13% (T0) to 42% (T2), and the incidence of depression increased from 10% to 36% ($P < 0.001$). HADS-A and HADS-D in the abnormal ECG group were significantly higher than those in the normal ECG group. There were significant differences in the incidence of anxiety (69.4% vs. 26.6%) and depression (55.6% vs. 25%) between the two groups ($P < 0.01$). The total score of PSQI was 5.49 ± 2.35 at T0, 7.53 ± 2.84 at T1, and 10.60 ± 3.67 at T2. ECG abnormalities were positively correlated with HADS-A ($r = 0.522$, $P < 0.01$), HADS-D ($r = 0.439$, $P < 0.01$) and PSQI ($r = 0.706$, $P < 0.01$). HADS-A ($r = 0.655$, $P < 0.01$) and HADS-D ($r = 0.547$, $P < 0.01$) were positively correlated with PSQI. **Conclusion:** Breast cancer patients undergoing anthracycline-based chemotherapy frequently exhibit characteristic ECG changes, including QT interval prolongation and ST-T segment abnormalities. These ECG abnormalities are associated with anxiety and depressive symptoms during treatment, as well as significantly aggravated sleep disturbances, suggesting a potential bidirectional interaction between cardiac function and neuropsychological health throughout the chemotherapy process.

Keywords: Breast cancer; anthracyclines; chemotherapy; electrocardiogram; sleep; anxiety;

depressed

1. Introduction

Breast cancer is the malignant tumor with the highest incidence in women worldwide and the second leading cause of cancer-related death in women [1]. In 2022, there will be 2.3 million new cases and 700,000 deaths of female breast cancer worldwide, accounting for 23.8% and 15.4% of all cancer cases and deaths, respectively [2,3]. The conventional clinical treatment of breast cancer includes surgery combined with radiotherapy, chemotherapy and endocrine therapy. As a kind of broad-spectrum and highly effective anti-tumor drugs, Anthracyclines are the first-line drugs for postoperative chemotherapy of breast cancer, which can improve the long-term survival rate of patients [4]. However, it has dose-dependent cardiotoxicity, which may cause serious complications such as arrhythmia, decreased myocardial contractility, and heart failure [5]. Studies have shown that about 30%~50% of patients receiving anthracycline-based chemotherapy develop subclinical ECG abnormalities and 5%~10% develop symptomatic cardiac insufficiency [6]. Von Hoff et al. [7] studied patients treated with anthracyclines and found that congestive heart failure and cardiomyopathy caused by anthracyclines occurred within 0–231 days after treatment, and their severity depended on the cumulative dose, and the early stage of anthracycline-induced cardiotoxicity was mostly subclinical myocardial damage [8,9]. Therefore, it is very important to monitor cardiac function and detect cardiac damage early during the use of anthracyclines. Myocardial injury not only increases the risk of cardiovascular events, but also may lead to the interruption of chemotherapy regimens, which in turn affects the effect of cancer treatment.

With the rise of oncologic cardiology, the monitoring, prevention and treatment of cardiotoxicity of anthracyclines has become a research hotspot. There are many methods for monitoring cardiotoxicity, such as cardiac magnetic resonance imaging, cardiac ultrasound, myocardial markers, electrocardiogram, etc. Existing studies mainly focus on the changes of echocardiographic parameters (such as left ventricular ejection fraction) and serum myocardial markers, but the systematic analysis of the dynamic evolution of Electrocardiogram (ECG) is still insufficient. This gap in research highlights the need for further investigation into ECG changes, which can serve as early indicators of cardiac dysfunction. ECG abnormalities, such as QTc prolongation and ST-T changes, often occur before cardiac structural abnormalities, which is an important window for early identification of cardiac damage.

In addition, cardiac complications induced by chemotherapy in breast cancer may trigger mood disorders such as anxiety and depression through the “somatic symptoms-psychological stress” interaction [10]. A meta-analysis showed that 33 out of 38 studies on depression observed depressive symptoms in breast cancer patients. Among the 21 studies on anxiety, 17 observed anxiety symptoms in breast cancer patients [11]. Psychological stress can aggravate the instability of myocardial electrical activity by activating sympathetic-adrenomedullary axis (SAM axis), while abnormal electrocardiogram may increase the psychological burden of patients through “somatic symptoms-psychological stress”, forming a vicious circle. In addition, chemotherapy-related cardiac complications can also disrupt the circadian

rhythm of patients, resulting in decreased sleep quality. At present, there is a lack of research on the correlation between ECG abnormalities and psychology and sleep in breast cancer patients undergoing chemotherapy at home and abroad. Based on the above background, this study further analyzed the effects of abnormal electrocardiogram on psychological mood and sleep quality by dynamically monitoring the changes of electrocardiogram parameters in breast cancer patients during anthracycline chemotherapy. The results of this study may provide evidence-based basis for formulating cardiac protection strategies and psychological intervention programs for patients receiving anthracycline-based chemotherapy.

2. Methods

2.1. Research design

This longitudinal observational study of breast cancer patients receiving anthracycline chemotherapy enrolled 100 patients between March 2021 and February 2024. The study was approved by the Ethics Review Board of Wuxi No.2 People's Hospital (Jiangnan University Medical Center) and informed consent from each patient was obtained before the study began.

Inclusion criteria: (1) Breast cancer confirmed by histopathology; (2) Age > 18 years old; (3) Receiving anthracycline chemotherapy for the first time; (4) Normal cognitive function.

Exclusion criteria: (1) Patients with autoimmune diseases or hematological diseases; (2) Coronary-heart-disease, myocarditis, myocardial infarction and other heart diseases before chemotherapy; (3) Complicated with other primary tumors; (4) Previous history of mental illness or disturbance of consciousness; (5) Distant metastasis.

2.2. ECG examination

Patients were monitored by electrocardiogram before receiving anthracycline-based chemotherapy (T0), after 2 cycles of chemotherapy (T1), and after 4 cycles of chemotherapy (T2). During the examination, patients were required to keep quiet and lie flat to avoid activities and emotional fluctuations. The paper speed for ECG recording was 25mm/s and the voltage was calibrated to 1mV = 10mm. The ECG results were interpreted independently by two experienced electrocardiologists, focusing on the following parameters: Heart rate (HR), PR interval, QT interval and QTc interval, ST segment changes (including ST segment elevation or depression $\geq 0.05\text{mV}$), T wave changes (T wave low, inverted or high sharp) and arrhythmia types (such as sinus tachycardia, sinus bradycardia, premature beat, atrioventricular block, etc.). If the results of two doctors were different, the final result was determined by discussion or consultation with a third doctor.

2.3. Research Tools

2.3.1. General information questionnaire

Demographic and clinical data were collected from the hospital case system,

including age, BMI, menopausal status, lesion location, TNM stage, molecular typing, ECOG, cumulative drug dose, hypertension, diabetes, and hyperlipidemia.

2.3.2. Hospital anxiety and depression scale (HADS)

The HADS [12] was used to assess the degree of anxiety and depression of the patients. The scale included two subscales of anxiety (HADS-A) and depression (HADS-D), and the total score was 21 points, 0~7 points indicated no symptoms, 8~10 points indicated suspicious existence, and 11~21 points indicated certain existence.

2.3.3. Pittsburgh sleep quality index (PSQI)

The PSQI [13] was used to assess the overall sleep quality of the patients, which included 7 items: subjective sleep quality, sleep latency, sleep time, sleep efficiency, sleep disturbance, sleep medication used and daytime dysfunction. Each item was scored from 0 to 3, and the total score ranged from 0 to 21, with higher scores indicating worse sleep quality.

2.4. Data collection

Data collection was performed by uniformly trained research staff. After the patient signed the informed consent form, the general information of the patient was recorded in detail. During chemotherapy, ECG data were collected in time. The psychological and emotional assessment scales and sleep quality assessment scales were completed by patients independently under the guidance of researchers to ensure the authenticity and reliability of the assessment results.

2.5. Statistical analysis

All the collected data were recorded into Excel tables for preliminary sorting and establishment of a database. SPSS 26.0 statistical software was used for data analysis. Measurement data were expressed as (mean $\pm$ SD). Independent sample t test was used for comparison between two groups, and ANOVA was used for comparison between multiple groups. The statistical data were expressed as the number of cases and percentage (*n*, %), and χ^2 test was used for comparison between groups. Pearson correlation analysis was used for correlation analysis. $P < 0.05$ was considered to be statistically significant.

3. Result

3.1. Patient baseline data

A total of 36 patients had abnormal ECG, and there were significant differences in age, BMI, menopausal status, TNM stage, cumulative drug dose, hypertension and hyperlipidemia between normal ECG group and abnormal ECG group ($P < 0.05$). It was found that patients with age ≥ 50 , BMI $\geq 24\text{kg/m}^2$, postmenopause, TNM stage III, cumulative dose $\geq 300\text{ mg/m}^2$, hypertension, and hyperlipidemia were more likely to develop abnormal electrocardiogram after chemotherapy. (**Table 1**)

Table 1. Patient baseline data.

	Total (n = 100)	Normal ECG group (n = 64)	Abnormal ECG group (n = 36)	t	p
Age				5.953	0.015
<50	41 (41.0)	32 (50.0)	9 (25.0)		
≥50	59 (59.0)	32 (50.0)	27 (75.0)		
BMI (kg/m ²)				10.447	0.001
<24	65 (65.0)	49 (76.6)	16 (44.4)		
≥24	35 (35.0)	15 (23.4)	20 (55.6)		
Menopausal status				8.734	0.003
Premenopausal	53 (53.0)	41 (75.0)	12 (52.7)		
Postmenopausal	47 (47.0)	23 (25.0)	24 (47.3)		
Location of lesion				0.362	0.547
Left	46 (46.0)	28 (43.7)	18 (50.0)		
Right	54 (54.0)	36 (56.3)	18 (50.0)		
TNM staging				4.243	0.039
II	58 (53.0)	42 (64.1)	16 (44.4)		
III	42 (39.0)	22 (35.9)	20 (55.6)		
Molecular typing				2.210	0.331
Luminal A/B	57 (57.0)	40 (62.5)	17 (47.2)		
Her-2 positive	29 (29.0)	16 (25.0)	13 (36.1)		
Triple negative	14 (14.0)	8 (12.5)	6 (16.7)		
ECOG				0.182	0.669
0	72 (72.0)	47 (73.4)	25 (69.4)		
1	28 (28.0)	17 (26.6)	11 (30.6)		
Cumulative dose of drugs				5.270	0.022
<300 mg/m ²	37 (37.0)	29 (45.3)	8 (22.2)		
≥300 mg/m ²	63 (63.0)	35 (54.7)	28 (77.8)		
Hypertension				4.097	0.043
Yes	11 (11.0)	4 (6.3)	7 (19.4)		
No	89 (89.0)	60 (93.7)	29 (80.6)		
Diabetes				1.316	0.251
Yes	5 (5.0)	2 (3.1)	3 (8.3)		
No	95 (95.0)	62 (96.9)	33 (91.7)		
Hyperlipidemia				4.101	0.043
Yes	7 (7.0)	2 (3.1)	5 (13.8)		
No	93 (93.0)	62 (96.9)	31 (86.1)		

3.2. ECG abnormalities in breast cancer patients during anthracycline chemotherapy

After chemotherapy, 20 patients (20%) had abnormal ECG at T1, and 36 patients (36%) had abnormal ECG at T2, and some patients had two or more abnormal ECG findings. There were 5 cases of sinus tachycardia, 1 case of sinus bradycardia, 2 cases of premature ventricular contraction, 2 cases of premature atrial contraction, 17 cases

of T wave change, 11 cases of ST segment depression, 16 cases of QTc prolongation, 4 cases of premature beat, 1 case of atrioventricular block, and 3 cases of bundle branch block. (**Table 2**)

Table 2. ECG abnormalities in breast cancer patients during anthracycline chemotherapy.

ECG abnormal type	T0	T1	T2	P-value
Total anomaly rate (n/%)	3 (3.0)	20 (20.0)	36 (36.0)	0.000
Sinus tachycardia	0 (0.0)	3 (3.0)	5 (5.0)	-
Sinus bradycardia	0 (0.0)	1 (1.0)	1 (1.0)	-
T-wave change	2 (2.0)	11 (12.0)	17 (17.0)	-
ST segment depression	1 (1.0)	6 (6.0)	11 (11.0)	-
QTc interval is prolonged	1 (1.0)	9 (9.0)	16 (16.0)	-
Premature ventricular contractions	0 (0.0)	1 (1.0)	2 (2.0)	-
Premature atrial contractions	0 (0.0)	0 (0.0)	2 (2.0)	-
Premature beats	0 (0.0)	2 (2.0)	4 (4.0)	-
Atrioventricular block	0 (0.0)	0 (0.0)	1 (1.0)	-
Right bundle branch block	0 (0.0)	1 (1.0)	3 (3.0)	-

3.3. HADS score changes and subgroup analysis of breast cancer patients before and after chemotherapy

Anxiety score (HADS-A) increased from 5.71 ± 2.24 (T0) to 9.74 ± 3.11 (T2) ($P < 0.001$). The depression score (HADS-D) increased from 5.06 ± 1.73 to 9.15 ± 2.80 ($P < 0.001$). The incidence of anxiety increased from 13 % (T0) to 42 % (T2), and the incidence of depression increased from 10 % to 36 % ($P < 0.001$). The HADS-A and HADS-D in the abnormal ECG group were significantly higher than those in the normal ECG group. There were significant differences in the incidence of anxiety (69.4% vs. 26.6%) and depression (55.6% vs. 25%) between the two groups ($P < 0.01$). (**Table 3, Figure 1**).

3.4. Comparison of PSQI scores of breast cancer patients before and after chemotherapy

The total PSQI score of patients was 5.49 ± 2.35 at T0, T1 increased to 7.53 ± 2.84 , and T2 further increased to 10.60 ± 3.67 ($P < 0.05$). With the increase of chemotherapy cycle, subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disorders, use of hypnotic drugs, and daytime dysfunction scores all showed an upward trend, indicating that patients' sleep quality gradually decreased during chemotherapy. (**Table 4, Figure 2**)

Table 3. HADS score changes and subgroup analysis of breast cancer patients before and after chemotherapy.

	T0	T1	T2	P-value	Abnormal ECG group (n = 36)	Normal ECG group (n = 64)	P-value
HADS-A	5.71 ± 2.24	8.08 ± 2.65	9.74 ± 3.11	<0.001	11.50 ± 3.67	8.75 ± 2.62	<0.001

Table 3. (Continued).

	T0	T1	T2	P-value	Abnormal ECG group (n = 36)	Normal ECG group (n = 64)	P-value
HADS-D	5.06 ± 1.73	7.44 ± 2.19	9.15 ± 2.80	<0.001	10.39±3.23	8.45±2.48	<0.01
Incidence of anxiety (n/%)	13 (13.0)	29 (29.0)	42 (42.0)	<0.001	25 (69.4)	17 (26.6)	<0.001
Incidence of depression (n/%)	10 (10.0)	25 (25.0)	36 (36.0)	<0.001	20 (55.6)	16 (25.0)	<0.01

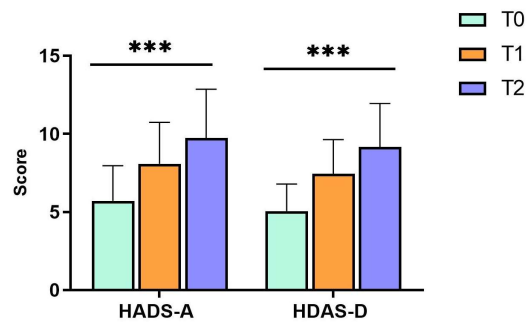


Figure 1. Longitudinal comparative analysis of HADS-A and HADS-D scores at different time points.

Table 4. Comparison of PSQI scores of breast cancer patients before and after chemotherapy.

Dimensionality	T0	T1	T2	P-value
Total PSQI score	5.49 ± 2.35	7.53 ± 2.84	10.60 ± 3.67	0.000
Subjective Sleep quality	0.85 ± 0.64	1.26 ± 0.59	1.74 ± 0.73	0.000
Sleep latency	1.17 ± 0.82	1.39 ± 0.92	2.01 ± 1.04	0.000
Sleep duration	0.98 ± 0.57	1.21 ± 0.76	1.53 ± 1.05	0.000
Sleep efficiency	0.22 ± 0.39	0.75 ± 0.61	1.39 ± 0.92	0.000
Sleep disorders	1.19 ± 0.40	1.38 ± 0.45	1.81 ± 0.56	0.000
Use of hypnotic drugs	0.12 ± 0.26	0.17 ± 0.38	0.25 ± 0.41	0.008
Daytime dysfunction	0.96 ± 0.73	1.37 ± 0.85	1.87 ± 0.85	0.000

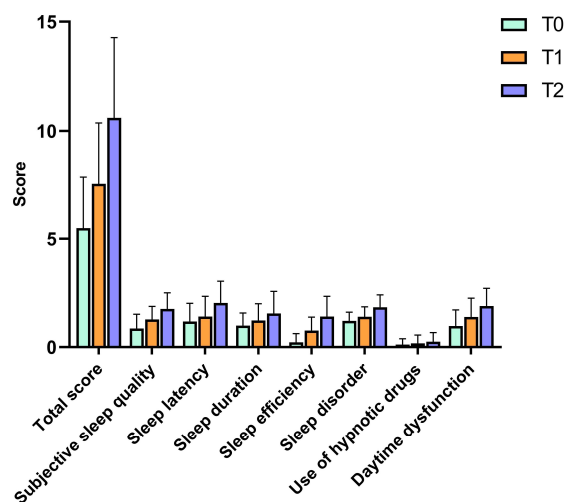


Figure 2. Comparison of PSQI scores at different time points.

3.5. Correlation analysis of abnormal ECG, anxiety, depression and sleep quality

There was a significant positive correlation between ECG abnormalities and HADS-A ($r = 0.522$, $P < 0.01$) and HADS-D ($r = 0.439$, $P < 0.01$), indicating that the more obvious the ECG abnormalities, the more serious the anxiety and depression of the patients. There was also a significant positive correlation between ECG abnormalities and sleep quality scores ($r = 0.706$, $P < 0.01$), indicating that the more serious the ECG abnormalities, the worse the sleep quality of patients. The anxiety score ($r = 0.655$, $P < 0.01$) and depression score ($r = 0.547$, $P < 0.01$) of the patients were significantly positively correlated with the sleep quality score, indicating that the more serious the anxiety and depression of the patients, the worse the sleep quality (Table 5).

Table 5. Correlation analysis of abnormal ECG, anxiety, depression and sleep quality.

	Abnormal ECG	HADS-A	HADS-D	PSQI
Abnormal ECG	-			
HADS-A	0.522**	-		
HADS-D	0.439**	0.481**	-	
PSQI	0.706**	0.655**	0.547**	-

** $P < 0.01$.

4. Discussion

In this study, 36% of breast cancer patients who received anthracycline-based chemotherapy had electrocardiographic abnormalities at T2 stage, mainly manifested as QTc interval prolongation, ST-segment depression, T wave changes, and arrhythmia, which may be related to the cardiotoxicity of anthracyclines. These findings highlight the significant prevalence of ECG abnormalities in patients undergoing treatment, emphasizing the need for vigilant cardiac monitoring during chemotherapy. Identifying these changes early can facilitate timely interventions that may mitigate the risk of severe cardiac complications. Previous studies have shown that the incidence of anthracycline-related ECG abnormalities ranges from 20% to 40% and is positively correlated with the cumulative dose [14,15]. This correlation underscores the importance of dose management in reducing the risk of cardiotoxicity, suggesting that careful consideration should be given to the total amount of anthracyclines administered to each patient. The prolongation of QTc interval is a potential marker of anthracycline-induced arrhythmia, and its mechanism may be related to drug interference with the function of potassium channels (such as hERG channels) in myocardial cells, resulting in prolonged repolarization time [16,17]. Understanding this mechanism is crucial for developing strategies to monitor and manage the risk of arrhythmias in patients receiving anthracyclines. The identification of QTc prolongation as a marker can lead to proactive measures, such as adjusting dosages or implementing additional monitoring protocols. Moreover, the prolongation of QTc interval may also increase the risk of torsades de pointes (TdP), especially when combined with hypokalemia or using other QT-prolonging drugs [18]. ST segment depression and T wave changes may reflect myocardial ischemia or

subclinical myocardial injury. These ECG changes can serve as critical indicators of underlying cardiac distress, prompting further investigation and intervention. Recognizing these signs early can be pivotal in preventing the progression of cardiac damage. Anthracyclines destroy the mitochondrial function of myocardial cells by producing reactive oxygen species (ROS) and induce apoptosis of myocardial cells, which affects the normal electrophysiological function and leads to changes in electrocardiogram [19]. This mechanism of action illustrates the profound impact of anthracyclines on cardiac health, reinforcing the necessity for ongoing research into protective strategies that can preserve cardiac function during cancer treatment. Therefore, early monitoring is essential to prevent events of serious cardiac damage.

In addition to cardiac damaging events, breast cancer patients often experience multiple psychological distress, such as anxiety and depression, during chemotherapy. A previous meta-analysis reported that the incidence of anxiety and depression in breast cancer patients reached 41.9% and 32.2%, respectively [20–22]. These statistics underscore the high prevalence of mental health issues among this patient population, necessitating integrated care approaches that address both physical and psychological needs. Lam [23] found that breast cancer patients in China experienced higher levels of anxiety and depressive symptoms. Lv et al. [24] Conducted a study on 290 breast cancer patients undergoing chemotherapy and found that the incidence of depression and anxiety was 31.4% and 20%. These findings highlight the need for routine mental health screenings in patients undergoing chemotherapy to identify and address these issues early. In this study, HADS-A and HADS-D scores of patients at T1 and T2 were significantly higher than those at T0, and the incidence of anxiety was 42% and the incidence of depression was 36% at T2, indicating that chemotherapy would have a significant impact on the anxiety and depression of patients. The increase in these scores reflects the cumulative stressors associated with cancer treatment, highlighting how ongoing therapy can exacerbate emotional challenges. The results were similar to those of previous studies. The reason may lie in: in the process of chemotherapy, the toxic side effects of drugs cause discomfort to the patient's body. These side effects not only affect physical health but also contribute to a heightened sense of vulnerability and fear regarding the treatment process. Anthracyclines may stimulate the gastrointestinal tract and cause nausea, vomiting, anorexia and other symptoms. These physical manifestations of discomfort can create a feedback loop, where the anticipation of side effects leads to increased anxiety, which in turn can exacerbate the perception of these symptoms. These adverse reactions can cause patients to have adverse emotions such as anxiety and depression. Hair loss is one of the common side effects of chemotherapy. Many patients suffer from hair loss after chemotherapy. This change in appearance will make female patients have low self-esteem. In addition, cancer-related fatigue, sleep disorders and other symptoms caused by chemotherapy can make patients extremely tired physically and mentally. This fatigue is not just physical; it can also lead to cognitive impairment and emotional exhaustion, further complicating the patient's ability to cope with treatment. All of these factors may trigger anxiety and depression in patients. In addition, patients' concerns about future treatment costs and treatment effects also affect their mood. Decreased sleep quality is a common accompanying symptom in breast cancer patients undergoing chemotherapy. One study showed that about 50% of patients had poor sleep during

various stages of chemotherapy [25]. In our study, patients had the lowest baseline PSQI score, and with the accumulation of chemotherapy cycles, the total PSQI score and the scores of each dimension showed a significant upward trend, suggesting that there was a dose-response relationship between the number of chemotherapy cycles and the degree of sleep disorders. From the perspective of pathophysiology, anthracycline chemotherapeutic drugs may mediate sleep disorders through multi-target mechanisms: first, drug-induced cancer-related fatigue can lead to excessive daytime sleepiness, and then cause circadian rhythm disorder [26]. Secondly, chemotherapeutic drug-mediated neurotoxicity may cause sleep rhythm disorder by interfering with the metabolic balance of neurotransmitters (such as serotonin and dopamine) in the central nervous system [27]. Finally, nausea, vomiting, abdominal pain and other adverse reactions caused by chemotherapy can also interfere with patients' sleep.

In addition, treatment-related anxiety and depression were closely related to sleep disorders. The results of this study showed that HADS-A score ($r = 0.655$, $P < 0.01$) and HADS-D score ($r = 0.547$, $P < 0.01$) of patients were significantly positively correlated with sleep quality score, indicating that the more serious the anxiety and depression of patients, the worse their sleep quality. Anxiety can cause patients to be in a hyperarousal state by activating the sympathetic nervous system, while depression-related anhedonia significantly reduces sleep efficiency. Studies have shown that anxiety and depression can affect the function of the hypothalamic-pituitary-adrenal axis (HPA axis), leading to abnormal secretion of stress hormones such as cortisol, and then interfere with sleep [28]. Abnormally elevated cortisol levels during the night can enhance noradrenergic neuronal activity in the locus coeruleus, thereby contributing to difficulty in maintaining sleep. Studies have shown that approximately 30%–40% of patients receiving anthracycline-containing regimens have difficulty falling asleep or sleep fragmentation [29]. It is worth noting that persistent sleep disorders can not only reduce the sensitivity of tumor cells to chemotherapy drugs by up-regulating the activity of NF- κ B pathway, but also may aggravate the negative emotions of patients, forming a vicious circle.

Based on research findings, it is recommended to implement regular ECG monitoring in clinical practice for breast cancer patients receiving anthracycline-based chemotherapy to enable early identification of cardiac abnormalities. For high-risk patients, prophylactic use of cardioprotective agents such as dexrazoxane should be considered, and a multidisciplinary team collaboration mechanism should be established to promptly assess and manage cardiac dysfunction. Additionally, particular attention should be paid to patients' psychological status and sleep quality. For those exhibiting anxiety/depression (HADS score ≥ 8) or poor sleep quality (PSQI score ≥ 7), psychological interventions (e.g., cognitive behavioral therapy, psychological counseling) and sleep management strategies should be implemented. Patients with moderate-to-severe symptoms should be referred to specialists, while strictly restricting the use of anti-anxiety medications and sleep aids. These comprehensive measures contribute to mitigating the cardiotoxic risks associated with anthracycline therapy while improving patients' psychological well-being and sleep quality.

This study has certain limitations: due to the constraints of its single-center design

and observation period, the relatively limited sample size and lack of long-term follow-up data may lead to selection bias or interference from confounding factors. Subsequent research plans to expand the sample size through multi-center collaboration and establish a 3–5-year longitudinal follow-up cohort, aiming to further investigate the associations between electrocardiographic parameters, psychological status, sleep quality, and their impact on clinical outcomes.

5. Conclusion

Breast cancer patients receiving anthracycline-based chemotherapy have characteristic electrocardiographic changes, such as QT interval prolongation and ST-T segment abnormalities. The dynamic changes of electrophysiological parameters may indicate subclinical cardiotoxicity. Notably, the patient's physiological changes correlated with worsening anxiety, depression, and significant sleep disturbances during treatment, suggesting a possible interaction between cardiac function and neuropsychological well-being during chemotherapy.

Author contributions: Designed the research study, WZ; performed the primary literature review, data extraction, WZ, QZ and SL; analyzed the data, wrote the manuscript, WZ, QZ and SL; responsible for revising the manuscript for important intellectual content, WZ. All authors have read and agreed to the published version of the manuscript.

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Ethical approval: The procedures for both T1 and T2 surveys adhered to the (i) Declaration of Helsinki, and (ii) ethical principles for medical, psychological, and sociological research involving human participants. The Wuxi No.2 People's Hospital Research Ethics committee approved the study protocol (approval number; (2024) Ethics Review No. (Y-242)).

Informed consent statement: Informed consent was obtained from all subjects involved in the study.

Conflict of interest: The authors declare no conflict of interest.

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