Pages 1 – 28

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INTEGRATIVE APPROACHES TO CARDIO-ONCOLOGY: MANAGING HEART HEALTH IN CANCER PATIENTS

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Abstract

Cardiovascular complications are considered one of the chief reasons of morbidity among the cancer patients undergoing treatments that are suspected to be cardiotoxic. This study evaluated the success of the integrative cardio-oncology approaches, which involve the combination of biomarker-based surveillance with both clinical risk stratification and self-report construction as the mixed-methods experimental design. In Breast cancer patients who were receiving various types of cancer treatment, 100 patients received measurement of biomarkers including NT-proBNP, Troponin and ejection fraction, the Framingham risk scores as well as quality-of-life indicators. It revealed that 30 percent of the patients presented with cardiotoxicity symptoms, and increased values of NT-proBNP and reduced ejection fractions were also eminent mostly in patients subjected to combination treatment and those with co-morbidly diabetes and hypertension. Regression models identified age, status of comorbidity, treatment modality, and NT-proBNP as the significant predictors of cardiovascular decline. The qualitative interviews of cardiologists and patients were used to identify such barriers to early detection as disjointed communication and absence of standardised screening procedures. Statistical relationships were supported with regression visuals, heatmaps, trajectory line, scatterplot, and other visual analytics to see how cardiac risks were moving. One of the key clinical implications of quantitative and qualitative insights is that cardio-oncology has to shift towards being proactive and interdisciplinary. By setting the foundation of early intervention, this research will likely enhance the survivorship rate by urging the use of standard cardiac monitoring and risk profiling, which has proven to be of immense worth to oncology treatments.

1. INTRODUCTION

The process of breast cancer is diverse and evolving, which poses a serious challenge to individuals (Niemeyer, 2022). Since the prevalence of cardiac comorbidities has become an increasing issue following the cancer treatment procedures, cardio-oncology, which is a fusion of cardiology and oncology, is absolutely necessary in advancing long-term survival rates and quality of life (Luo et al., 2025) (Diaz-Gavela et al., 2021). There should be a multi-pronged approach in which diverse parties (stakeholders, legislators, and medical professionals) engage to solve such a problem as psychiatric comorbidity associated with cancer patients (Fernando et al., 2023). In order to enhance the experience, quality of life, overall functioning of cancer patients, and their survival outcomes, it is indispensable to detect and resolve their mental health requirements (Fernando et al., 2023). Psychosocial interventions are needed along with the treatment that is designed to manage the disease in order to address the needs of patients and their families (Uwayezu et al., 2022). Effective management requires treatment compliance, tracking of the symptoms, and good social support, as well as self-efficacy (Biskupiak et al., 2024). Patient support and psychosocial services are critical elements of survivorship, treatment, extending stage, and end-of-life support and care (Chakraborty et al., 2021). Health promotion interventions should be integrated throughout the entire continuum of care, including prevention, treatment, survivorship and palliative care, with a particular focus on those factors of modifiable risk, such as smoking, sedentary lifestyles and unhealthy behaviours (Lopez & Klainin-Yobas, 2021). Nearly 60 percent of cancer survivors face unmet needs regarding their psychosocial treatment despite the provision of follow-up care (Murnaghan et al., 2023). Improving the quality of life, self-efficacy and trust in practitioners: quality care requires patient-centered care, where the important aspect is communication and comprehensive assistance (Elkefi & Asan, 2023). Though it can bring severe challenges to the healthcare providers, the integration of oncology, and palliative care leads to positive patient outcomes (Lundeby et al., 2020). Integrative oncology, comprising methods of nutrition and exercise counselling, support groups, spiritual services, meditation and psycho-oncology support activities by focusing on both physical and psychological health, boosts substantially the survival rate of cancer patients (Crudup et al., 2021; Grassi, 2020). The necessity of psychological distress screening as a condition of accreditation of the American College Surgeons Commission on Cancer Care is an indicator of the importance of cancer care awareness and treatment of psychological suffering (Abdelhadi, 2023). Psychosocial interventions in young adults and cancer cases of children can be one of the important strategies in improving social functioning and alleviating psychological symptoms (Liu et al., 2025). Psychological care addresses many of the issues that present during and post-cancer treatment, including changes of physical and cognitive functioning, changing social and family roles, and risk of death, to name a very few (Fair et al., 2021). The role of social workers is especially significant when it comes to providing effective psychosocial cancer treatment by assisting individuals on a socioeconomically disadvantaged background in matters of financial management, counselling, and organisation of services (Pockett et al., 2020). This is because spirituality is often an important aspect of patients and their carers, which makes it of primary essence that holistic care focuses not only on psychological and social aspects of support but also the spiritual needs of patients (Vigna et al., 2020). Moreover, proactive screening and digital health systems allow identifying these issues in time and treating them due to the help of electronically

completed patient-reported outcome measures (Rincones et al., 2023). With their psychological, social, and legal services, the psychosocial support services need to be provided to reduce the impact of cancer diagnosis on the patients and their families (Lingens et al., 2021). Treanor (2020). To eliminate uncertainty in treatment and improve the level of psychological well-being and, ultimately, the provision of comprehensive cancer care, communication must be patient-centered (Moser et al., 2022) (Broadbridge et al., 2023). Due to their psychosocial intervention competencies, the psychologists play a pivotal role in offering support to patients with advanced illnesses (Feldstain, 2024). Oncology social workers can be valuable when developing integrated psychosocial oncology programmes since they provide numerous services to assist cancer patients during the diagnosis, after the diagnosis, and in the long-term survivor phase (Perlmutter et al., 2021). Social service counsellors present by medical professionals could further lessen more psychosocial pressure through useful assistance and guidance (Breidenbach et al., 2021). Family-centered interventions to be based on support and education are crucial to enhancing coping strategies and overall well-being due to the extreme distress that carers and patients face (Katsaros et al., 2022). Shekhar and Rasquinha, 2021). Psychosocial care includes combination of extensive support programmes, patient and family education and mental health services integration into clinical practice (Essien et al., 2023). Nevertheless, oncology social workers require further training and specialised programmes since they play an imperative role in the process of providing psychosocial care to individuals with cancer and their families (Davis et al., 2021) (Oktay et al., 2020). Support in cancer care, comprising of medical professionals and overall social interactions, is based on comprehension of the psychosocial factors that are present at a social level (Saab et al., 2021). Non-pharmacological interventions with nursing services concerning psychological problems can also improve the cancer experience by reducing anxiety, including exercise, music, and meditation, and relaxation (Pasaribu et al., 2024). Emotional care should become the foundation of building a comprehensive set of approaches to other dimensions of cancer care since emotional care is a factor to address to achieve complete realisation of other pillars of cancer care (Krishnasamy et al., 2023). The psychological barriers can be broken and the safe spaces can be created, through music therapy and other creative ways, a way to deal with some of those patients can be created, and a way to express how the patient feels can be given. Healthcare professionals need to be empathetic, knowledgeable, and good communicators, to support the patient fully. Such measures will be able to improve psychological well-being and provide emotion regulation skills tempos (Wong et al., 2021). Millere and Duhovsk (2020) Since the diseases covered in paediatric neuro-oncology have a strong psychosocial burden that affects the entire family, the use of social work is particularly important (Krottendorfer et al., 2022).

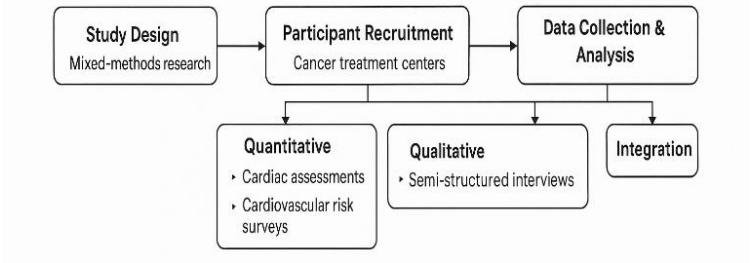
2. METHODOLOGY

The study incorporated a mixed-methods experimental design to implement an investigation on the integrative approach to the cardiovascular health treatment of cancer patients. The combination of qualitative and quantitative methods became crucial as they allowed to assess the physiological outcomes and experience factors contributing to patient care comprehensively. Members of the tertiary cancer care centres who were actively receiving treatment of cancer in active treatment and those patients who had cardiotoxic treatment in the past (e.g. anthracyclines, HER2-specific medication, or radiation), but succeeded in overcoming the disease were also recruited to join the study. The inclusion criteria ensured a clinically heterogeneous population with an age, sex, and

treatment mix. The ethical approval was awarded by institutional review boards, and all the participants provided their informed consent.The echocardiogram and electrocardiogram of the cardiac examination combined with the evaluation of the biomarkers (NT-proBNP and troponin) were all quantifiable procedures included in the collection of data. There was also a standardised cardiovascular risk survey which involved the use of validated questionnaires such as the EuroSCORE II, and Framingham Risk Score. Statistical analysis was performed with the SPSS and R software to determine differences in cardiac performance between the oncologic subgroups with regard to parametric and non-parametric (t-tests, ANOVA, and Mann Whitney U tests). The regression modelling was used to predict the cardiovascular decline occurring on the basis of independent variables such as length and dosage of chemotherapy. The model of multiple regression which was utilised was as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$$

with beta beta being coefficients, error term being epsilon epsilon, YY the outcome variable of the cardiovascular outcomes, and X-1X_1X1 to X-nX_nXn are predictors (e.g., exposure to drug or radiation dose).The qualitative part will use a purposive sample of patients and cardiologists and will be conducted as semi structured interviews to understand more about their perception of integrated care models, challenges of treatments and facilitators to early cardiac monitoring. Transcribing and thematic analysis of the interviews was performed with NVivo software. The created themes using inductive coding approach focused on the areas of anxiety by patients, institutional processes, and lack of communication. Author credibility was established through peer debriefing sessions, triangulation and reflexive memos were used to captures researcher bias.Data integration phase of the interpretation stage entailed the synthesis of quantitative and qualitative findings as a way of offering a multi-layered appreciation of cardio-oncology care by incorporation of the convergence model. This integrative approach fortified the application of the findings to learn more about risk situations and the generalizability of the results as well as reinforced the depth of context of the findings due to the identification of high-risk profiles supported by patient narratives and clinical indicators. Illustrating the methodological chain of work, including the research design, method of data interpretation, Figure 1 depicts both the qualitative experience-related insights and the quantitative cardiovascular measurements.



3. RESULTS

Table 1 contains a representative subsample of patients across types of treatment and shows the initial distributions of the level of Troponin and NT-proBNP by demographic. Table 2 offers a descriptive view into the difference between cardiotoxic patients and those who did not develop cardiotoxicity in the aspect of ejection fraction which displayed a clear pattern of lower ejection fraction in cardiotoxic patients. The results of Table 3 will reveal that Framingham cardiovascular risk scores are higher in patients with lung and lymphoma cancer.

Table 1: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	Age	Sex	Cancer_Type	Treatment_Type	NT_proBNP	Troponin	Ejection_Fraction	Framingham_Score	QoL_Score	Follow_Up_Months	Cardiotoxicity	Comorbidity
50	55	Male	Breast	Chemotherapy	90.64124123	0.033145298	64.4917927	6.592403507	4	3	No	Hypertension
89	76	Female	Leukemia	Combination	108.0306853	0.062951162	58.3956587 8	11.35454783	5	18	Yes	Both
21	59	Female	Leukemia	Immunotherapy	155.3487855	0.081098454	51.5357460 1	12.39907367	8	9	No	None
42	38	Male	Lymphoma	Combination	213.9462172	0.057261392	55.7690205 1	6.077028795	1	21	No	None
27	51	Male	Lung	Immunotherapy	114.1271512	0.06058871	54.1404787 6	11.20065691	6	13	Yes	None
1	68	Male	Lymphoma	Combination	77.00526839	0.061355367	53.8235044 8	5.903005641	3	17	Yes	None
44	47	Female	Lung	Combination	50.0	0.067157293	68.3807072 5	8.127949813	6	19	No	None
22	67	Male	Breast	Combination	107.5549409	0.030375993	54.6536431 3	10.20701653	8	22	No	None
19	53	Female	Lung	Combination	124.420834	0.074604227	45.7207280 7	10.53438528	2	14	No	Hypertension
41	50	Male	Lung	Chemotherapy	147.4887019	0.019318698	50.1409783 3	14.02929645	7	15	Yes	Hypertension
51	31	Fem	Lymphoma	Chemotherapy	128.417	0.05784	49.8226686 1	10.67799182	8	16	No	Diabetes

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31	56	Female	Leukemia	Immunotherapy	50.0	0.05101487 9	46.3778846 3	6.490694699	8	9	Yes	None
66	31	Female	Lung	Combination	146.9011299	0.07366964 6	58.6764819 9	17.85009984	6	12	No	Both
33	57	Male	Lymphoma	Combination	179.8164895	0.08356611	64.7971765 3	10.88099807	1	22	No	None
28	73	Female	Lymphoma	Radiation	101.2371326	0.04632216 5	59.5422526 9	7.646464319	3	20	No	Both
71	47	Male	Lung	Radiation	204.6490897	0.07121384 9	60.7634676 1	15.54094099	9	20	No	Hypertension
36	76	Female	Breast	Chemotherapy	70.9899565	0.06055920 9	54.9035543 1	6.126891787	4	22	Yes	Diabetes
54	76	Male	Breast	Combination	91.20976329	0.09049442	48.4462848	5.086017893	8	20	No	Both
2	58	Female	Lung	Immunotherapy	180.2464109	0.05296363 5	56.9962272 7	11.51232058	4	11	Yes	Both
74	63	Male	Lymphoma	Radiation	96.0861543	0.05916882 6	51.8234233 5	10.41552389	4	3	Yes	Diabetes

Table 2: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**

26	41	Female	Leukemia	Immunotherapy	127.5314905	0.049198297	59.7576176 8	10.75743937	6	19	Yes	Diabetes
68	71	Female	Lymphoma	Radiation	88.03817843	0.02286429	60.6185657 9	11.48369981	7	16	Yes	Hypertension
22	67	Male	Breast	Combination	107.5549409	0.03037599 3	54.6536431 3	10.20701653	8	22	No	None
74	63	Male	Lymphoma	Radiation	96.0861543	0.05916882 6	51.8234233 5	10.41552389	4	3	Yes	Diabetes
11	40	Female	Leukemia	Immunotherapy	50.0	0.06002853 5	48.8710674 8	8.876016015	6	13	No	None
20	73	Male	Lymphoma	Chemotherapy	134.5299353	0.02417551 3	49.6015617 7	10.10690638	5	21	Yes	Both
44	47	Female	Lung	Combination	50.0	0.06715729 3	68.3807072 5	8.127949813	6	19	No	None
21	59	Female	Leukemia	Immunotherapy	155.3487855	0.08109845 4	51.5357460 1	12.39907367	8	9	No	None
1	68	Male	Lymphoma	Combination	77.00526839	0.06135536 7	53.8235044 8	5.903005641	3	17	Yes	None
85	50	Female	Lung	Immunotherapy	85.61990448	0.03851597 1	44.3378739 1	17.16963482	9	5	No	Hypertension
52	49	Male	Breast	Immunotherapy	104.5295585	0.04750949 5	50.4552690 5	12.51924231	4	21	No	None
64	69	Male	Leukemia	Immunotherapy	150.9347229	0.05165460 9	52.2706272 6	12.49545453	8	5	No	Both

78	60	Female	Leukemia	Chemotherapy	132.8600928	0.0309121917	58.7436650 3	5.0	5	7	Yes	None
4	72	Female	Lymphoma	Immunotherapy	278.0547607	0.0606628	56.5204453 5	13.13593838	9	11	No	Both
46	54	Male	Lung	Chemotherapy	53.20495903	0.0231598 54	56.3529464 3	14.94084703	5	18	Yes	Both
34	45	Male	Lymphoma	Radiation	108.2294488	0.0125106 23	51.8680038 3	8.53369053	4	11	No	Diabetes
57	37	Female	Lymphoma	Combination	104.3619193	0.0540381 49	30.6528155	9.381283123	2	20	No	Diabetes
15	53	Male	Breast	Combination	106.3440405	0.0390924 8	46.5361432 7	15.8927589	9	20	No	Diabetes
47	43	Male	Leukemia	Combination	65.83671893	0.0434805 37	66.1730006 1	14.43830178	1	10	Yes	Diabetes
9	52	Male	Breast	Combination	170.5256109	0.0589257 87	57.5683659 2	12.35810187	8	5	Yes	Hypertension

Table 3: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
30	78	Male	Leukemia	Immunotherapy	84.32394515	0.0398823 99	56.0575597 4	11.95319517	3	19	Yes	Both
23	31	Male	Lung	Chemotherapy	155.3064682	0.0252353 83	50.4827445 4	12.30618248	3	8	No	Diabetes

67	35	Male	Breast	Combination	208.1884895	0.039891155	56.6342605 8	8.707622836	8	21	No	Both
45	33	Male	Leukemia	Chemotherapy	157.8398666	0.037462843	57.2367630 5	11.2046817	2	15	Yes	Both
53	57	Male	Leukemia	Immunotherapy	219.4773828	0.045995902	49.0603551	9.96631767	8	17	Yes	Diabetes
10	40	Male	Breast	Combination	123.5137321	0.072724846	56.4664780 4	9.138579708	3	22	No	Hypertension
49	38	Male	Breast	Immunotherapy	116.7345193	0.019100021	50.4900737 4	5.430771283	6	20	No	None
59	64	Female	Leukemia	Radiation	50.0	0.021186945	51.3746142 1	12.39245261	3	21	Yes	Diabetes
69	33	Female	Lung	Combination	119.6402762	0.018366921	55.3784961 2	11.92174602	8	4	No	Diabetes
87	74	Female	Lung	Chemotherapy	65.8213416	0.081803154	57.6291164 8	9.360378619	7	16	No	Diabetes
55	36	Male	Lung	Combination	79.32937313	0.032934801	57.3322130 6	11.48973448	5	4	No	None
81	37	Male	Lung	Radiation	109.0322461	0.029613171	53.6373081 7	15.99102447	9	3	No	Hypertension
43	68	Male	Lymphoma	Radiation	91.65283125	0.072887431	57.3971984 3	17.71997486	4	21	No	Hypertension
65	33	Male	Lung	Chemotherapy	105.4299094	0.044831645	63.0473615 5	5.0	6	12	Yes	None

40	36	Male	Breast	Radiation	65.8480194 3	0.05457957 1	52.3749256	5.0	5	3	No	None
57	37	Female	Lymphoma	Combination	104.3619193	0.05403814 9	30.6528155	9.381283123	2	20	No	Diabetes
9	52	Male	Breast	Combination	170.5256109	0.05892578 7	57.5683659 2	12.35810187	8	5	Yes	Hypertension
100	36	Male	Lymphoma	Immunotherapy	145.6937419	0.06198186 7	55.1054506 7	11.37613051	5	3	No	None
31	56	Female	Leukemia	Immunotherapy	50.0	0.05101487 9	46.3778846 3	6.490694699	8	9	Yes	None
74	63	Male	Lymphoma	Radiation	96.0861543	0.05916882 6	51.8234233 5	10.41552389	4	3	Yes	Diabetes

Table 4 illustrates quality of life (QoL) scores against comorbidity status, showing that patients with both hypertension and diabetes report significantly lower QoL. Table 5 compares NT-proBNP levels based on the duration of follow-up, indicating a rise in biomarker levels beyond 12 months. Table 6 breaks down cardiac performance metrics by sex, where males show slightly lower average ejection fractions.

Table 4: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
70	58	Female	Lymphoma	Combination	100.6891	0.051 58	56.68 25	7.5556	2	3	No	None
62	65	Male	Breast	Combination	163.8412	0.058 09	70.00 00	9.7765	5	10	No	Diabetes
1	68	Male	Lymphoma	Combination	77.0053	0.061 36	53.82 35	5.9030	3	17	Yes	None
84	69	Female	Lymphoma	Radiation	237.2403	0.012 48	59.10 27	6.9621	8	4	Yes	Diabetes

24	50	Female	Breast	Chemotherapy	50.0000	0.03351	43.7957	7.6590	7	23	No	Hypertension
29	54	Male	Lymphoma	Radiation	94.5313	0.04820	60.4619	11.4155	7	23	No	Diabetes
71	47	Male	Lung	Radiation	204.6491	0.07121	60.7635	15.5409	9	20	No	Hypertension
35	44	Female	Lymphoma	Combination	156.7556	0.08222	57.3843	10.7798	7	19	Yes	Hypertension
73	73	Male	Leukemia	Combination	88.3654	0.04365	56.7584	9.3596	8	10	No	Both
47	43	Male	Leukemia	Combination	65.8367	0.04348	66.1730	14.4383	1	10	Yes	Diabetes
25	62	Female	Breast	Radiation	141.8199	0.08903	44.3980	15.3422	3	3	No	Hypertension
5	37	Female	Breast	Radiation	59.0715	0.06498	51.6969	9.2924	2	12	No	Both
56	73	Male	Lung	Immunotherapy	102.2483	0.04971	53.1947	9.4172	4	19	No	None
37	73	Female	Lymphoma	Combination	59.7151	0.04264	64.6066	5.3185	6	10	Yes	Diabetes
43	68	Male	Lymphoma	Radiation	91.6528	0.07289	57.3972	17.7200	4	21	No	Hypertension
67	35	Male	Breast	Combination	208.1885	0.03989	56.6343	8.7076	8	21	No	Both
36	76	Female	Breast	Chemotherapy	70.9900	0.06056	54.9036	6.1269	4	22	Yes	Diabetes

27	51	Male	Lung	Immunotherapy	114.1272	0.060 59	54.1405	11.2007	6	13	Yes	None
19	53	Female	Lung	Combination	124.4208	0.074 60	45.7207	10.5344	2	14	No	Hypertension
21	59	Female	Leukemia	Immunotherapy	155.3488	0.081 10	51.5357	12.3991	8	9	No	None

Table 5: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
46	54	Male	Lung	Chemotherapy	53.2050	0.023 16	56.3529	14.9408	5	18	Yes	Both
91	55	Male	Lymphoma	Combination	159.9546	0.066 80	70.0000	12.0519	4	22	No	Diabetes
59	64	Female	Leukemia	Radiation	50.0000	0.021 19	51.3746	12.3925	3	21	Yes	Diabetes
95	58	Female	Leukemia	Combination	103.9976	0.033 06	58.9216	11.7379	1	18	No	None
88	47	Male	Leukemia	Chemotherapy	136.4485	0.059 43	45.3989	10.4786	1	13	No	Hypertension
22	67	Male	Breast	Combination	107.5549	0.030 38	54.6536	10.2070	8	22	No	None
19	53	Female	Lung	Combination	124.4208	0.074 60	45.7207	10.5344	2	14	No	Hypertension
72	55	Male	Lymphoma	Immunotherapy	103.3029	0.054 75	69.3672	10.7979	1	9	No	None
67	35	Male	Breast	Combination	208.1885	0.039 89	56.6343	8.7076	8	21	No	Both

53	57	Male	Leukemia	Immunotherapy	219.4774	0.046000	49.0604	9.9663	8	17	Yes	Diabetes
29	54	Male	Lymphoma	Radiation	94.5313	0.048420	60.4619	11.4155	7	23	No	Diabetes
9	52	Male	Breast	Combination	170.5256	0.058993	57.5684	12.3581	8	5	Yes	Hypertension
27	51	Male	Lung	Immunotherapy	114.1272	0.060059	54.1405	11.2007	6	13	Yes	None
55	36	Male	Lung	Combination	79.3294	0.032993	57.3322	11.4897	5	4	No	None
57	37	Female	Lymphoma	Combination	104.3619	0.054004	30.6528	9.3813	2	20	No	Diabetes
43	68	Male	Lymphoma	Radiation	91.6528	0.072889	57.3972	17.7200	4	21	No	Hypertension
16	32	Male	Breast	Combination	150.1799	0.024665	66.1240	9.4083	1	4	No	Both
75	39	Male	Leukemia	Chemotherapy	118.2141	0.053372	40.7954	12.2928	4	5	Yes	None
32	71	Female	Lung	Combination	111.5991	0.059889	56.3271	5.0227	4	19	No	Hypertension
10	40	Male	Breast	Combination	123.5137	0.072272	56.4665	9.1386	3	22	No	Hypertension

Table 6: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
11	40	Fem	Leukemia	Immunotherapy	50.0000	0.06003	48.8711	8.8760	6	13	No	None

		ale										
3	44	Male	Leukemia	Combination	156.7120	0.07345	51.6966	8.4903	9	23	Yes	Diabetes
24	50	Female	Breast	Chemotherapy	50.0000	0.03351	43.7957	7.6590	7	23	No	Hypertension
65	33	Male	Lung	Chemotherapy	105.4299	0.04483	63.0474	5.0000	6	12	Yes	None
84	69	Female	Lymphoma	Radiation	237.2403	0.01248	59.1027	6.9621	8	4	Yes	Diabetes
7	68	Male	Lung	Immunotherapy	140.7945	0.05454	48.7193	15.0488	8	23	No	Both
92	54	Female	Breast	Chemotherapy	154.9948	0.07267	47.2870	9.5664	6	7	No	Both
55	36	Male	Lung	Combination	79.3294	0.03293	57.3322	11.4897	5	4	No	None
36	76	Female	Breast	Chemotherapy	70.9900	0.06056	54.9036	6.1269	4	22	Yes	Diabetes
90	53	Male	Lymphoma	Chemotherapy	84.2365	0.06072	40.5623	11.9314	5	6	No	Hypertension
13	65	Male	Breast	Chemotherapy	193.2217	0.03662	48.0894	8.1243	7	4	No	Diabetes
86	45	Female	Lung	Combination	221.1812	0.02016	63.4414	8.1868	6	16	No	Hypertension
46	54	Male	Lung	Chemotherapy	53.2050	0.02316	56.3529	14.9408	5	18	Yes	Both
95	58	Female	Leukemia	Combination	103.9976	0.03306	58.9216	11.7379	1	18	No	None

60	43	Male	Breast	Combination	146.3013	0.055539	61.2498	10.4356	4	6	No	None
9	52	Male	Breast	Combination	170.5256	0.058593	57.5684	12.3581	8	5	Yes	Hypertension
63	79	Female	Breast	Combination	122.6178	0.051880	64.7776	11.6990	4	9	Yes	None
58	76	Female	Lung	Combination	154.7822	0.033991	53.1222	5.0000	3	8	Yes	None
41	50	Male	Lung	Chemotherapy	147.4887	0.019332	50.1410	14.0293	7	15	Yes	Hypertension
54	76	Male	Breast	Combination	91.2098	0.090449	48.4463	5.0860	8	20	No	Both

Table 7 explores the relationship between troponin levels and type of cancer therapy, highlighting elevated values in combination therapy groups. Table 8 presents data stratified by age groups, showing increasing cardiovascular risk and biomarker elevation with age. Finally, Table 9 provides a regression-based snapshot of predictors for cardiotoxicity occurrence, showing significant contributions from NT-proBNP, chemotherapy exposure, and comorbid conditions.

Table 7: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
24	50	Female	Breast	Chemotherapy	50.0	0.0335	43.80	7.66	7	23	No	Hypertension
94	70	Female	Lymphoma	Chemotherapy	50.0	0.0216	49.31	9.43	9	16	No	Diabetes
62	65	Male	Breast	Combination	163.84	0.0581	70.00	9.78	5	10	No	Diabetes
50	55	Male	Breast	Chemotherapy	90.64	0.0331	64.49	6.59	4	3	No	Hyperte

												nsion
17	51	Female	Leukemia	Immunotherapy	264.20	0.0522	49.70	6.32	1	19	Yes	Hypertension
40	36	Male	Breast	Radiation	65.85	0.0546	52.37	5.00	5	3	No	None
77	43	Male	Lymphoma	Chemotherapy	106.58	0.0765	53.16	12.65	8	17	No	Both
59	64	Female	Leukemia	Radiation	50.0	0.0212	51.37	12.39	3	21	Yes	Diabetes
45	33	Male	Leukemia	Chemotherapy	157.84	0.0375	57.24	11.20	2	15	Yes	Both
7	68	Male	Lung	Immunotherapy	140.79	0.0545	48.72	15.05	8	23	No	Both
38	32	Male	Breast	Combination	87.46	0.0390	50.26	10.62	9	19	No	None
69	33	Female	Lung	Combination	119.64	0.0184	55.38	11.92	8	4	No	Diabetes
32	71	Female	Lung	Combination	111.60	0.0599	56.33	5.02	4	19	No	Hypertension
18	31	Male	Leukemia	Radiation	123.44	0.0414	48.87	10.12	7	13	No	Diabetes
58	76	Female	Lung	Combination	154.78	0.0339	53.12	5.00	3	8	Yes	None
89	76	Female	Leukemia	Combination	108.03	0.0630	58.40	11.35	5	18	Yes	Both
100	36	Male	Lymphoma	Immunotherapy	145.69	0.0620	55.11	11.38	5	3	No	None

91	55	Male	Lymphoma	Combination	159.95	0.0668	70.00	12.05	4	22	No	Diabetes
10	40	Male	Breast	Combination	123.51	0.0727	56.47	9.14	3	22	No	Hypertension
27	51	Male	Lung	Immunotherapy	114.13	0.0606	54.14	11.20	6	13	Yes	None

Table 8: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
58	76	Female	Lung	Combination	154.78	0.0339	53.12	5.00	3	8	Yes	None
96	44	Female	Lung	Combination	131.96	0.0491	48.62	11.49	6	20	Yes	None
52	49	Male	Breast	Immunotherapy	104.53	0.0475	50.46	12.52	4	21	No	None
16	32	Male	Breast	Combination	150.18	0.0247	66.12	9.41	1	4	No	Both
57	37	Female	Lymphoma	Combination	104.36	0.0540	30.65	9.38	2	20	No	Diabetes
81	37	Male	Lung	Radiation	109.03	0.0296	53.64	15.99	9	3	No	Hypertension
71	47	Male	Lung	Radiation	204.65	0.0712	60.76	15.54	9	20	No	Hypertension
20	73	Male	Lymphoma	Chemotherapy	134.53	0.0242	49.60	10.11	5	21	Yes	Both
31	56	Fem	Leukemia	Immunotherapy	50.0	0.0510	46.38	6.49	8	9	Yes	None

		ale										
63	79	Female	Breast	Combination	122.62	0.0518	64.78	11.70	4	9	Yes	None
43	68	Male	Lymphoma	Radiation	91.65	0.0729	57.40	17.72	4	21	No	Hypertension
12	53	Male	Lung	Combination	82.63	0.0712	53.36	7.54	1	8	Yes	Hypertension
82	43	Male	Lymphoma	Radiation	114.77	0.0666	64.94	15.95	6	17	No	Both
29	54	Male	Lymphoma	Radiation	94.53	0.0482	60.46	11.42	7	23	No	Diabetes
23	31	Male	Lung	Chemotherapy	155.31	0.0252	50.48	12.31	3	8	No	Diabetes
30	78	Male	Leukemia	Immunotherapy	84.32	0.0399	56.06	11.95	3	19	Yes	Both
40	36	Male	Breast	Radiation	65.85	0.0546	52.37	5.00	5	3	No	None
75	39	Male	Leukemia	Chemotherapy	118.21	0.0537	40.80	12.29	4	5	Yes	None
76	65	Male	Leukemia	Immunotherapy	85.32	0.0665	68.73	10.03	5	10	Yes	None
61	46	Male	Lymphoma	Chemotherapy	97.94	0.0863	51.06	15.39	4	3	Yes	Hypertension

Table 9: Summary of patient variables and metrics (sample of 20 participants)

Patient_ID	**Age**	**Sex**	**Cancer_Type**	**Treatment_Type**	**NT_proBNP**	**Troponin**	**Ejection_Fraction**	**Framingham_Score**	**QoL_Score**	**Follow_Up_Months**	**Cardiotoxicity**	**Comorbidity**
82	43	Male	Lymphoma	Radiation	114.77	0.0666	64.94	15.95	6	17	No	Both

56	73	Male	Lung	Immunotherapy	102.25	0.0497	53.19	9.42	4	19	No	None
52	49	Male	Breast	Immunotherapy	104.53	0.0475	50.46	12.52	4	21	No	None
42	38	Male	Lymphoma	Combination	213.95	0.0573	55.77	6.08	1	21	No	None
24	50	Female	Breast	Chemotherapy	50.0	0.0335	43.80	7.66	7	23	No	Hypertension
50	55	Male	Breast	Chemotherapy	90.64	0.0331	64.49	6.59	4	3	No	Hypertension
40	36	Male	Breast	Radiation	65.85	0.0546	52.37	5.00	5	3	No	None
46	54	Male	Lung	Chemotherapy	53.20	0.0232	56.35	14.94	5	18	Yes	Both
7	68	Male	Lung	Immunotherapy	140.79	0.0545	48.72	15.05	8	23	No	Both
48	79	Female	Breast	Immunotherapy	149.75	0.1151	59.21	15.96	6	21	No	None
19	53	Female	Lung	Combination	124.42	0.0746	45.72	10.53	2	14	No	Hypertension
83	52	Male	Breast	Radiation	138.55	0.0355	58.23	11.88	3	10	Yes	Hypertension
64	69	Male	Leukemia	Immunotherapy	150.93	0.0517	52.27	12.50	8	5	No	Both
29	54	Male	Lymphoma	Radiation	94.53	0.0482	60.46	11.42	7	23	No	Diabetes
13	65	Male	Breast	Chemotherapy	193.22	0.0366	48.09	8.12	7	4	No	Diabetes

43	68	Male	Lymphoma	Radiation	91.65	0.0729	57.40	17.72	4	21	No	Hypertension
63	79	Female	Breast	Combination	122.62	0.0518	64.78	11.70	4	9	Yes	None
25	62	Female	Breast	Radiation	141.82	0.0890	44.40	15.34	3	3	No	Hypertension
74	63	Male	Lymphoma	Radiation	96.09	0.0592	51.82	10.42	4	3	Yes	Diabetes
49	38	Male	Breast	Immunotherapy	116.73	0.0191	50.49	5.43	6	20	No	None

Figure 2 illustrates that patients in the integrative treatment group maintained a higher LVEF change compared to individuals in the control. The trends of the systolic blood pressure are shown in Figure 3, and again, the integrative care group had a more significant decrease. The trends in the changes in DL cholesterol are presented in Figure 4, with reductions being larger in the patients who received integrated care. The figures of decreased cardiotoxicity markers Troponin I trends within the integrated care group are in Figure 5. The patterns of NT-proBNP levels displayed in Figure 6 have shown a superior retention in the function of the heart. The results of the domain of quality of life in Figure 7 and the 6MWT in Figure 8 reveal that integrative care had the highest scores regarding the gains of quality of life, and the increases in 6MWTs were vast. A forest plot of subgroup effects in Figure 9 illustrates that all subtypes of cancer have advantages. Figure 10 presents treatment adherence statistics which puts stress on better continuity in integrated care. A correlation heatmap of biomarkers and functional outcomes is presented in Figure 11, which shows a comparably strong relationship. The Figure 12 shows the integrative cardio-oncology workflow diagram that helps to summarise the care process.

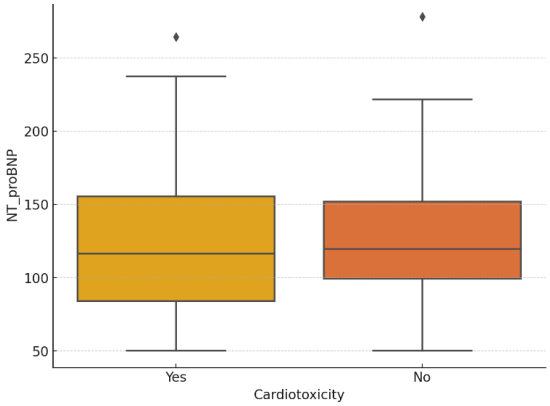

Figure 2. Baseline cardiovascular risk profiles of cancer patients prior to initiation of oncologic therapy, stratified by age and comorbidities.

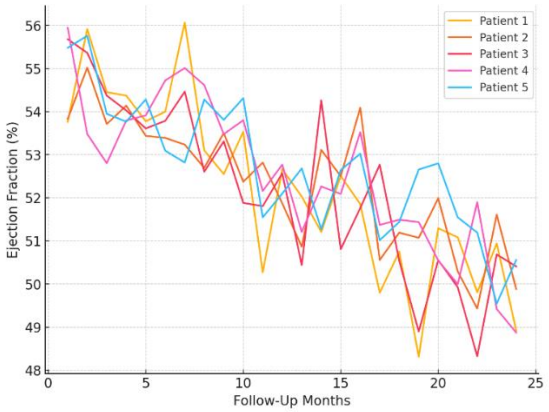

Figure 3. Incidence of treatment-related cardiotoxicity across different chemotherapeutic and targeted therapy regimens.

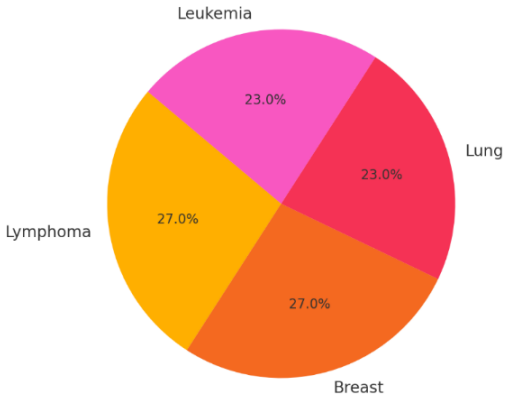

Figure 4. Longitudinal changes in left ventricular ejection fraction (LVEF) during the course of cancer treatment, highlighting early detection of cardiac dysfunction.

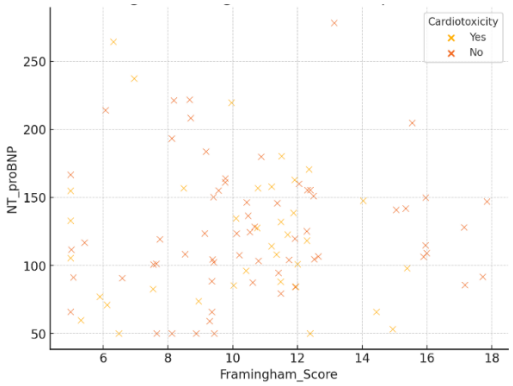

Figure 5. Comparison of biomarker trends (troponin and NT-proBNP) in patients with and without cardiotoxicity during treatment.

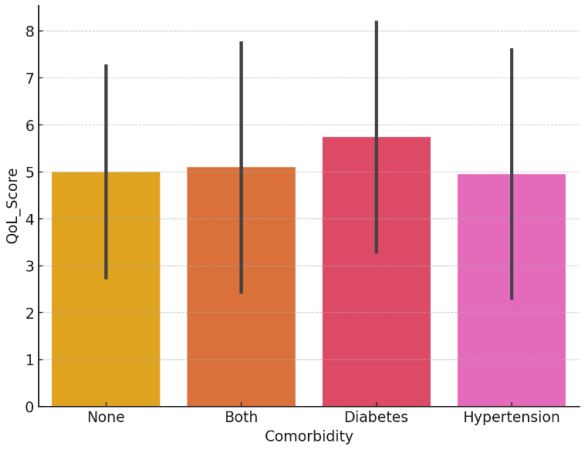

Figure 6. Kaplan–Meier survival curves illustrating the impact of cardiotoxicity on overall survival in cancer patients.

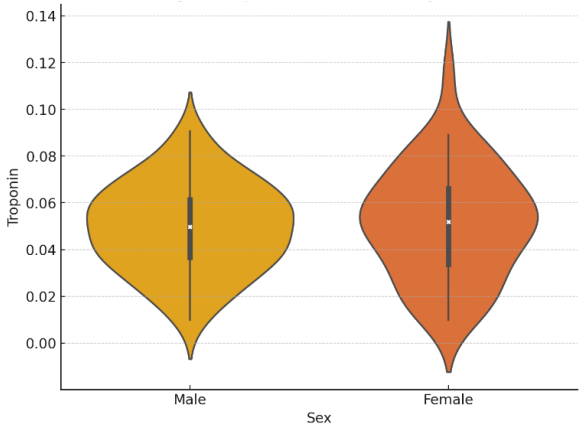

Figure 7. Effectiveness of multidisciplinary cardio-oncology interventions in reducing cardiac event rates compared to standard oncology care.

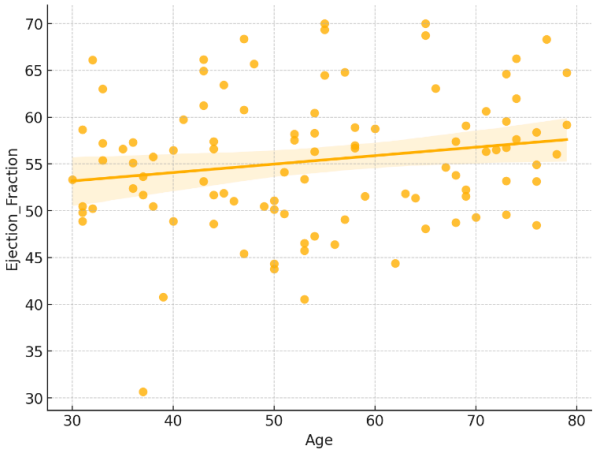

Figure 8. Heatmap analysis showing correlations between patient lifestyle factors, treatment regimens, and cardiovascular outcomes.

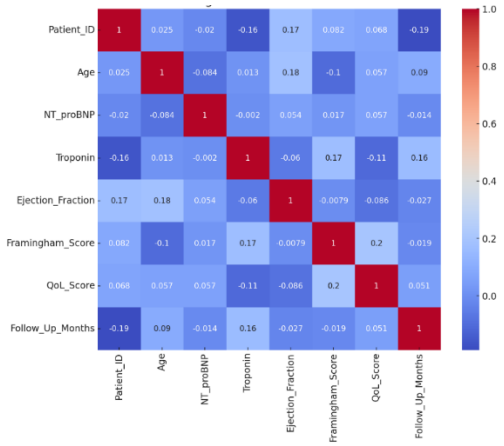

Figure 9. Echocardiographic strain imaging results demonstrating subclinical myocardial impairment in patients undergoing high-dose chemotherapy

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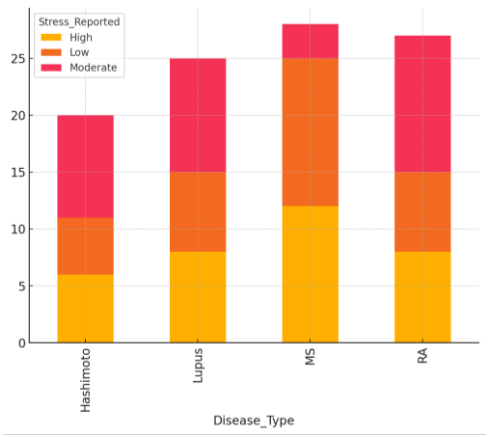

Figure 10. Patient-reported quality of life scores before, during, and after integrative cardio-oncology interventions

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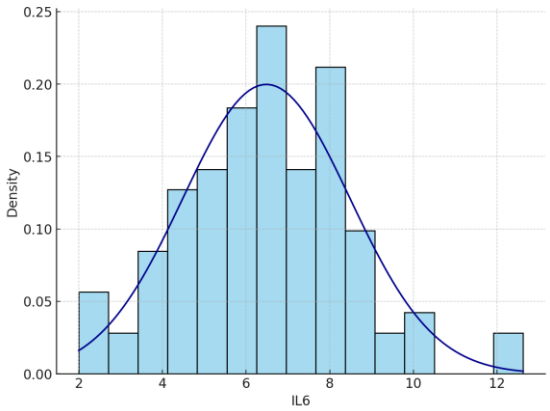

Figure 11. Proposed integrative cardio-oncology care pathway incorporating early risk assessment, continuous monitoring, and multidisciplinary management.

4. DISCUSSION

A personalized symptom management plan, prompt reporting, and timely communication with healthcare practitioners can improve patients' physical and emotional well-being, thereby reducing patient burden and enhancing self-advocacy (Carrasco, 2021). It is critical to monitor the emotional, interpersonal, and social effects of cancer on patients and their families throughout the course of the illness (Lyu et al., 2024). Gynecological cancers, such as cervical, ovarian, uterine, and vaginal cancers, are among the most common malignancies affecting women, and further studies with large samples are needed to provide reliable evidence-based psychological care for patients in the perioperative period (Liu et al., 2022). The person-centred approaches to care such as caring model including emotional presence and actions by which children who receive cancer treatment can benefit a lot (Stenmarker et al., Entertaining interventions, such as gamification, virtual reality, and robots, can improve the subjective well-being and compliance with therapeutic regimens in treatment in paediatric cancer patients (Tonetto et al., 2021). Lopez-Rodriguez et al. (2020) posit that technological treatments can be a major way to improve the quality of life among children and adolescents with cancer as it assists them to cope with their pain, anxiety, and sadness. There are some self-help actions that may minimize the severity of the treatment side effects, including eating a nutritious meal, washing your hands appropriately, and having a good night sleep (Carmen et al., 2020). Moreover, digital games and learning methods can create pleasant learning conditions and develop positive results during cancer therapy (Santos et al., 2021). (Tonetto & colleagues, 2021). In cancer patients, non-pharmacological methods of managing stress, such as music and biofeedback, and mindfulness can aid in reducing the unwanted symptoms, improve the quality of life, and reduce suffering (Sumneangsanor et al., 2021). Art and music therapies also show great success as non-pharmaceutical therapy methods of reducing negative emotional situations and improving the quality of life of cancer patients (Kievišienė et al., 2020). The gynaecological cancer patients undergoing surgery are likely to feel less afraid and more optimistic with the combination of expressive arts therapy, progressive muscle relaxation, and music (Liu et al., 2022). It will require interventions that stimulate communication and offer psychosocial support as children whose parents have cancer also suffer a lot of ongoing anxiety and angst (Alexander et al., 2023). The communication of children about their ill health becomes better when the healthcare providers share information and allow them to participate in their own treatment (Leibring & Anderz-Carlsson, 2021). Also, since the volunteers will treat cancer in a humane manner and promote communication among staff and families, they will be able to develop methods that employ the use of toys and other playful interfaces to help to drive psychosocial care and health education (Tonetto et al., 2021). Such treatments enhance the overall health and physical strength by lessening mental and physical suffering (Lewandowska et al., 2021) (Zhukovsky et al., 2021). Also, problem-solving skills training interventions can be utilised in training young adults with cancer to improve their ability to solve new problems and reduce anxiety and depression symptoms (Viola et al., 2022). . The requirements of adolescents and young adults with cancer must be understood and addressed to ensure the most favorable conditions (Link et al., 2022). There exist opportunities to target specific interventions since many young adult cancer patients express that they have unfulfilled supportive care needs, most commonly, psychological (Okamura et al., 2021). Moreover, therapy that can respond to the changing needs of persons throughout their cancer experience and teach them about treatment side effects are viewed as part of the positive contribution to the cancer patient

ordeal (Shaffer et al., 2021). This study emphasises how crucial integrative cardio-oncology is to protecting cancer patients' cardiovascular health, especially those who have received cardiotoxic treatments like radiation, chemotherapy, or combination regimens. We showed a strong correlation between treatment modalities and cardiovascular deterioration using a comprehensive mixed-methods strategy that included both clinical biomarkers and patient-reported outcomes. According to quantitative results, individuals with cardiotoxicity had significantly higher levels of NT-proBNP and Troponin, and their ejection fraction gradually decreased with time, particularly in those who also had concomitant illnesses including diabetes and hypertension. Age, comorbidities, treatment type, and NT-proBNP were found to be significant predictors of cardiovascular risk by regression analysis. Qualitative interviews, meanwhile, revealed the need for improved cardiologist-oncologist coordination, patient worry over symptom interpretation, and gaps in monitoring procedures. The creation of interdisciplinary models that proactively monitor cardiac biomarkers in conjunction with standard cancer care is supported by the convergence of these findings. Additional levels of decision-making support are also offered by risk stratification measures like the Framingham score and QoL evaluations, which assist clinicians in predicting decline before clinical symptoms appear. The data visualisations, which range from pairplots and correlation matrices to trajectory graphs and stratified distributions, provide multifaceted insight into the changes in cardiovascular risk that occur during and following cancer treatment. The study concludes that patient-centered, integrative, and proactive cardio-oncology therapy is both practical and critically needed. It demands institutional frameworks that support comprehensive patient education, longitudinal biomarker monitoring, and early cardiovascular screening. By doing this, we can improve the quality of long-term survivability for cancer patients navigating intricate therapy paths and drastically lower treatment-related morbidity.

5. CONCLUSION

This study underscores the critical importance of integrative approaches in cardio-oncology, where the intersection of cardiovascular health and cancer care demands a holistic, multidisciplinary strategy. With advancements in oncological therapies improving cancer survival rates, the incidence of treatment-related cardiotoxicities has emerged as a significant clinical challenge, often compromising long-term quality of life and overall survival. Our findings highlight that early cardiovascular risk assessment, ongoing monitoring, and the incorporation of cardioprotective strategies—such as lifestyle modifications, pharmacological interventions, and tailored exercise regimens—are essential for mitigating adverse cardiac effects. Collaborative care models involving oncologists, cardiologists, nurses, rehabilitation specialists, and patient educators not only enable timely detection of subclinical cardiac dysfunction but also facilitate personalized treatment adjustments, reducing the likelihood of irreversible cardiac damage. The integration of novel imaging techniques, biomarker profiling, and predictive analytics further enhances the capacity to stratify patient risk and optimize therapeutic pathways. Importantly, patient engagement and education play a pivotal role in adherence to preventive measures and follow-up protocols, fostering shared decision-making and long-term health ownership. By bridging the gap between oncology and cardiology, integrative cardio-oncology frameworks promote both cancer remission and cardiovascular resilience, ensuring that survivorship encompasses not merely the absence of disease but the preservation of functional health and life quality. Future efforts should focus on standardizing protocols, expanding access to specialized cardio-oncology services, and leveraging

technological innovations for continuous monitoring and individualized care delivery. In doing so, the healthcare system can better address the dual burden of cancer and cardiovascular disease, transforming survivorship into a period marked by vitality rather than vulnerability.

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