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Meta-Analysis and Systematic Review

Comparative Review of Internet of Things Applications in Continuous Monitoring of Cancer Patients and Their Impact on Quality of Life

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Abstract

Background: The integration of internet of things (IoT) technologies into cancer care has created new opportunities for real-time patient monitoring and personalized treatment management. Although research findings suggest the usefulness of these technologies, it is unclear how well they can be implemented in practice, how well patients accept them, and what impact they have on quality of life (QoL) for people with cancer.

Objective: This systematic review and meta-analysis aimed to evaluate the feasibility, patient acceptance, and clinical impact of IoT-based interventions on the QoL in cancer patients.

Methods: Thirty-three studies with over 7800 patients across a range of cancers were reviewed. Interventions included wearable devices, mobile applications, and integrated IoT platforms combining sensors, apps, and clinician dashboards to measure treatment progress, QoL, and early detection of complications. Treatment adherence, QoL outcomes, and early detection of adverse events were analyzed, and a meta-analysis was conducted for 12 studies.

Results: The results showed that the use of IoT technologies has high feasibility and acceptance, with adherence rates ranging from 63% to 98%. The type of device affected both adherence and effectiveness. For example, wearable gadgets alone improved QoL to some extent, but integrated IoT systems had the greatest impact on symptom management, patient engagement, and overall improvement in QoL. This meta-analysis demonstrated a moderate positive effect, with an SMD of approximately 0.48, confirming a moderate positive effect on QoL. Breast cancer patients benefited the most, especially in reducing fatigue and improving sleep and physical activity. These technologies also support continuous monitoring, early detection of adverse events, timely interventions, and potential reduction in healthcare costs.

Conclusion: IoT-based technologies, especially integrated platforms, have been shown to effectively improve QoL of cancer patients, especially in those with breast cancer. The right combination of devices and a user-friendly design plays a major role in improving outcomes. However, technical difficulties, low long-term participation, and poor digital literacy remain challenges. Future research should focus on developing standardized protocols, examining long-term outcomes, using artificial intelligence, and implementing this technology equitably across patient populations.

Keywords: Internet of things, Cancer, Quality of life

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Background

Healthcare systems are steadily shifting their course and moving toward patient-centered models that prioritize patients' needs rather than focusing solely on treating disease. This change is due to technological advances and innovations that have made everything smarter and more personalized.[1,2] The internet of things (IoT), when combined with advanced technologies such as 5G communications, secure data storage using blockchain, and artificial intelligence (AI), including machine learning (ML), and deep learning (DL), has the potential to revolutionize oncology (i.e., cancer treatment and investigation) by fundamentally changing treatment trajectories.[3] The convergence of IoT, cognitive computing, ML, and big data offers new avenues for enhancing cancer care.[4] IoT devices, including wearables and environmental sensors, can monitor vital parameters such as heart rate, blood pressure, oxygen saturation, glucose levels, heart rhythm, and physical activity, as well as detect environmental and behavioral changes relevant to a patient's health.[4-8]

The IoT is a network of interconnected devices that can exchange data with one another. This exchange of information enables a wide range of smart applications and services that are more convenient and intelligent.[2] In healthcare, the IoT is becoming a valuable source of digital data and biomarkers, largely due to the use of active and passive sensors that can record vital body

information in real time and transmit it to clinicians or smart systems.[8,9] Advances in technology have made it easier and more accurate to perform tasks such as remote patient monitoring, earlier detection of complications, designing personalized treatment planning, and even more effective follow-up of treatment progress.[10,11] In oncology in particular, the intelligent integration of IoT can simplify processes ranging from point-of-care testing to chemotherapy monitoring and follow-up planning. It can also continuously track symptoms and treatment side effects to ensure a more accurate and controlled recovery process.[12]

Cancer remains one of the world's greatest health challenges and the second leading cause of death after heart disease, claiming an estimated 9.6–10 million lives each year.[3,5] In addition to treatment side effects such as nausea, pain, shortness of breath, insomnia, loss of appetite, constipation, or diarrhea, many patients also struggle with comorbidities such as diabetes, osteoporosis, depression, or chronic fatigue, all of which make the treatment process more difficult and burdensome.[13-16] Cancer management today involves a combination of different treatment modalities, including surgery, immunotherapy, chemotherapy, radiotherapy, and hormone therapy. Most of these treatments are delivered on an outpatient basis, meaning that patients must self-manage their condition, handle side effects, and regularly monitor their health.[17-20]

Smart devices, especially mobile health (mHealth) applications that work with IoT wearables, have become a new source of support for cancer patients, helping them navigate their recovery journey more easily and confidently during treatment.[3] mHealth technology enables real-time data collection, accurate symptom tracking, and access to educational content. In this way, patients are not only recipients of care but become actively involved in their own health care and gain greater control over their recovery.[21,22] For example, wearable monitors and portable biosensors have been used to help patients undergoing chemotherapy or radiotherapy to reduce fatigue, reduce the risk of hospitalization, and improve mental health.[18,22,23] Evidence suggests that the use of IoT, mHealth, and eHealth in oncology has grown significantly over the past decade—especially in the past five years. However, most existing studies remain experimental or pilot in nature, and the number of robust randomized controlled trials (RCTs) is still limited, indicating a need for more rigorous and robust research.[24-30]

With the growth of IoT-based systems, Internet-based telemonitoring platforms have emerged as a complementary approach to cancer patient follow-up and have become an important component of modern oncology care.[31-34] Traditional follow-up programs, which are often complex and costly, may not adequately meet patients' real needs and may even impose additional logistical and financial burdens.[35] By enabling the transmission of clinical data through connected devices and digital applications, telemonitoring facilitates earlier identification of symptoms, earlier intervention, and constant communication between patients and healthcare providers, thereby helping to overcome many shortcomings and problems of traditional programs.[36,37] Preliminary research suggests that such systems can help cancer patients manage symptoms more effectively, improve their quality of life, and reduce the likelihood of hospitalization.[38-42]

Thus, when the IoT is integrated into oncology care, it essentially brings together two key innovations in health: continuous physiological monitoring and telehealth platforms. This approach can not only increase recovery and treatment outcomes but also significantly improve patients' quality of life by reducing treatment burden, reducing unnecessary hospitalizations, and enabling personalized care plans. Given the rapid technological advances and the evolving body of evidence, a comparative review of IoT applications for continuous monitoring of cancer patients—focusing specifically on their impact on quality of life—is warranted.

Methods

Study Design

This study is a comparative systematic review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The main objective was to investigate how IoT technologies were used for continuous monitoring of cancer patients and their impact on patients' quality of life (QoL), to identify, analyze, and compare these applications.

Data Sources and Search Strategy

A comprehensive search of electronic databases such as PubMed, Scopus, and Web of Science was conducted. The search focused on studies published between January 2013 and June 2025 to capture the most recent technological advances and clinical evidence, as the use of IoT in cancer care had increased dramatically after 2013.

Search terms were developed using Medical Subject Headings (MeSH) and related keywords. Finally, the query string was combined using Boolean AND/OR operators as follows:

("Internet of Things" OR IoT OR "wearable devices" OR "remote monitoring" OR "smart health") AND ("cancer" OR "oncology" OR "tumor" OR "neoplasm") AND ("continuous monitoring" OR "remote patient monitoring" OR "real-time monitoring") AND ("quality of life" OR QoL OR "patient-reported outcomes")

In addition to database searches, the reference lists of the selected articles were also manually checked to identify any studies that may have been missed in the initial search.

Eligibility Criteria

Inclusion Criteria

- Studies that directly examined the use of IoT-based

systems for continuous monitoring of cancer patients.
- Studies that assessed QoL, patient-reported outcomes, or clinically relevant indicators of QoL.
- Articles published in English or with at least an English abstract.

Exclusion Criteria
- Studies that focused solely on technical design or system architecture, without actual patient evaluation.
- Animal studies or purely simulation-based studies.
- Studies that did not report QoL-related outcomes.
- Conference abstracts without full-text access or informal narrative reviews.

Study Selection Process
Two reviewers independently conducted the initial search and removed duplicates using EndNote X9. Titles and abstracts were screened for relevance, and full-text articles were assessed for eligibility criteria. Any disagreements were resolved either through discussion or consultation with a third senior reviewer.

Data Extraction
A standardized form was designed to systematically record the following data:
- Bibliographic details (title, authors, year, journal)
- Cancer type and characteristics of the target population
- IoT technology specifications (sensors, devices, platforms, algorithms)
- Monitoring modality (continuous, intermittent, remote)
- QoL measurement tools (e.g., EORTC QLQ-C30, FACT-G)
- Quantitative and qualitative outcomes
- Reported limitations and implementation challenges

Data extraction was performed independently by two reviewers, followed by cross-checking and validation to ensure accuracy.

Quality Assessment and Risk of Bias
The methodological quality of RCTs was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool, while observational studies were assessed using the Newcastle-Ottawa (NOS) scale.

Each study was scored independently by two reviewers, and the mean score was recorded. Disagreements were resolved by consensus.

Data Synthesis and Comparative Analysis
Findings were synthesized using comparative and validity analysis, and studies were categorized according to the following criteria:
- Type of cancer
- Type of IoT technology
- QoL assessment framework

Where sufficient homogeneity existed, a meta-analysis was conducted using RevMan 5.4, calculating effect sizes with 95% confidence intervals (CIs). Heterogeneity was assessed using the I^2 statistic.

Ethical Considerations
As this study only reviewed previously published studies, no formal ethics committee approval was required. All sources were carefully cited, and the entire review process adhered to the principles of transparency, reproducibility, and avoidance of any data distortion.

Results
Study Selection and Characteristics
A total of 33 studies published between 2013 and June 2025 were included in this systematic review, as illustrated in Figure 1.

The detailed characteristics of the reviewed studies are presented in Tables 1 and 2. Collectively, these studies included 7,821 cancer patients aged 18 to 87 years. The distribution of cancer types in the reviewed studies was as follows:
- Breast cancer: 10 studies (30.3%)
- Gastrointestinal cancers: 7 studies (21.2%)
- Lung cancer: 5 studies (15.1%)
- Prostate cancer: 2 studies (6.0%)
- Other cancers (blood, head and neck, and pediatric cancers): 9 studies (27.4%)

Regarding IoT-based interventions:
- Wearable devices were used in 22 studies (67%).
- mHealth apps and telemedicine platforms were used in 18 studies (54%).
- IoT systems integrated with ML algorithms were implemented in 9 studies (28%).

The most commonly used tools for measuring patients' QoL were:
- EORTC QLQ-C30: 7 studies
- FACT-G / FACT-Endocrine: 5 studies
- SF-12 / SF-36: 4 studies
- Other tools, including PROMIS, PRO-CTCAE, and custom-designed digital platforms: 17 studies.

Impact of Internet of Things-Based Interventions on Quality of Life
Studies Reporting Significant Quality of Life Improvement
Among the reviewed studies, 21 studies (63%) showed significant and meaningful improvements in at least one area of patients' QoL after using IoT-based interventions (Table 2). These improvements mainly included enhanced social functioning, reduced fatigue, improved sleep quality, greater treatment adherence, and an overall better sense of well-being.

Studies have shown that IoT-based monitoring systems can substantially support cancer patients by greatly improving the treatment experience through real-time symptom tracking, personalized care, and remote management of treatment complications.

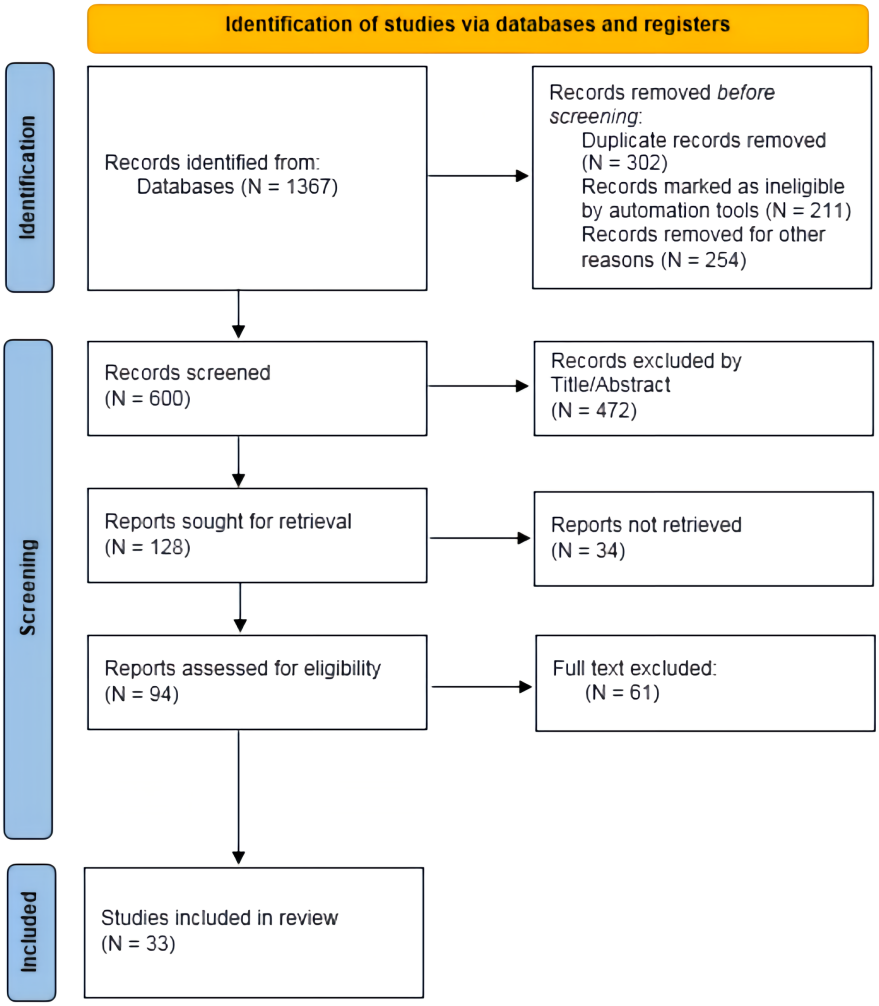

Figure 1. PRISMA Flow Diagram Illustrating the Selection Process of Studies Included in the Systematic Review

Studies Reporting No Significant Effect on Quality of Life

In contrast, seven studies (about 21%) found no significant change in patients' QoL after IoT-based interventions (Table 2). Although these studies reported improvements in communication and care coordination, they did not observe significant differences in patient-reported QoL scores. The effectiveness of these types of interventions may depend more on factors such as patient participation, adherence to program requirements, and duration of follow-up.

This body of studies suggests that the effectiveness of IoT-based interventions is influenced by the level of patient involvement and participation, adherence to the treatment plan, and the length of follow-up periods.

Studies Without Quality of Life Assessment

The remaining five studies did not directly measure QoL; instead, they focused on related issues, such as technology usability, patient satisfaction, adherence to treatment, and overall system feasibility. However, these studies showed high acceptability of IoT platforms and highlighted their potential to both improve clinical workflow and increase patient engagement, even when QoL was not formally measured.[43,44,48,55,68]

Patient Adherence and Technology Acceptance

High levels of patient adherence have been consistently reported across studies (Table 2). Overall, approximately 85% of individuals were receptive to the technology, indicating that these systems are well-accepted.

Wearable devices: User adherence ranged from 63% to 95%, with an average acceptance of 87%. This means that most people accepted these devices, but the level of adherence varied from person to person.

Mobile health apps: Adherence ranged from 68% to 92%, with an average acceptance of 81%, slightly lower than that of wearable devices, where adherence was reported as average.

Integrated IoT platforms: Adherence ranged from 70% to 98%, with an average acceptance of 90%. These platforms demonstrated the highest adoption and sustained engagement, demonstrating that integrating multiple devices and services strengthens users' engagement with the system. That is, the more tools are combined, the stronger the user's relationship with that system becomes.

Table 1. Summary Characteristic of Included Studies and Patient Populations in Systematic Review

Authors /Year	Study Type	Cancer Type	Sample Size	Technology / IoT
Melstrom et al[43] (2022)	Proof-of-concept trial with real patients	GI (colorectal, gastric, pancreas, liver, peritoneal surface) and urologic cancers (kidney, bladder)	21 (median age 58, range 32–82)	FDA-cleared Bluetooth devices (thermometer, scale, sphygmomanometer, pulse oximeter), Garmin Vivofit 4 pedometer, Aetonix A Touch Away™ app
van de Weerd et al[44] (2022)	Mixed-methods study (survey + semi-structured interviews)	HNC	216 invited; 135 completed MAUQ (mean age 66.2 ± 9.7; 63% male); 13 interviewees	RMA integrated in EPIC MyChart EHR; monthly self-monitoring with symptom questionnaire + guided self-exam (video); case manager review
Graetz et al[45] (2024)	RCT (3-arm, nonblinded, intention-to-treat)	Early-stage HR + Breast Cancer (DCIS, stage I–III)	304 women (EUC = 104, App = 98, App + Feedback = 102); mean age 58.6 y	Remote monitoring app integrated with EHR + electronic pillbox (Wisepill) + tailored weekly text messages
Peterson et al[46] (2021)	Feasibility studies (3 sub-studies, pilot)	CRC (n = 50), HNC (n = 37), Tobacco Treatment Program survivors (n = 50)	CRC = 50, HNC = 37, TTP = 50	CYCORE system with Home Health Hub; BP monitor, weight scale, accelerometer, HR monitor, GPS, CO monitor, smartphone app (PRO + video upload)
Cheng[4] et al[7] (2021)	Prospective observational cohort study (single-center, China)	Lung cancer (post-surgical patients)	826 eligible; 589 responded adequately (≥3 surveys)	Smartphone messenger app (WeChat) for symptom surveys
Daly et al[48] (2022)	Quality improvement study (real-world, single-center, prospective program analysis)	Solid tumors and lymphoma (thoracic, head and neck, GI most common)	217 patients (median age 66, range 31–92)	MSK Patient Portal (smartphone/tablet/ computer interface, HIPAA-compliant)
Leyva et al[49] (2023)	Project report + 3 case studies (model development)	Surgical oncology (mixed, not specified clearly)	3 case studies	Remote PGHD platform + wearable sensors + electronic symptom reporting
Barillaro et al[50] (2024)	Pilot prospective study	Breast cancer (during radiotherapy)	36 invited, 32 compliant (89% compliance)	Fitness tracker (Veepoo H03 smartwatch: heart rate, step count, sleep, SpO_2 monitoring0; gateway-based data transfer to hospital server
Leonardsen et al[51] (2022)	Qualitative study (in-depth interviews + thematic analysis)	Mixed cancer patients (not specified by subtype)	11 patients (6 female, 5 male, mean age 56, range 45–83)	Telephone, video consultations (Zoom, Skype), software/tablets with questionnaires
Park et al[52] (2021)	Prospective, multicenter, RCT	Prostate cancer (patients on ADT)	172 enrolled (86 SAC, 86 control); final analysis 148	SAC platform: smartphone app + smartband (Neofit) + web platform (Bluetooth → HL7 data transfer); daily activity, exercise, diet, BP, glucose monitoring
Mooney et al[53] (2024)	RCT (SCH vs. Usual Care)	Mixed cancers, patients on chemotherapy	358 patients	SCH: automated digital remote monitoring system with daily symptom reporting, automated self-care coaching, and nurse follow-up
Pavic et al[54] (2020)	Prospective, single-center, observational feasibility study	Palliative cancer patients (various cancers, life expectancy > 8 weeks, < 12 months)	30 (25 completed)	Smartphone with pre-installed "Activity Monitoring" app + sensor-equipped bracelet (wearable)
Grøndahl et al[55] (2022)	Qualitative interview study (explorative, descriptive)	Mixed cancers (oncology and hematology departments)	10 healthcare professionals (4 physicians, 6 nurses)	Telephone, tablets, video conferencing (remote monitoring tech during COVID-19)
Ghods et al[56] (2021)	Quantitative cohort study	GI cancers (mainly colon, undergoing chemo)	27 patients (median age 58, 63% male)	Consumer wearable activity tracker (Misfit Shine)
Yunis et al[57] (2024)	Single-arm, prospective pilot study	Mixed cancers (breast 34%, GI 24%, gynecologic 24%, thoracic/skin 14%, other 4%) – majority stage III–IV	50 patient–caregiver dyads (100 participants)	Smartphone apps: DigiBioMarC (patients), TOGETHERCare (caregivers)
Minvielle et al[58] (2024)	Ancillary analysis of Phase 3 RCT (SEM)	Mixed cancers (patients on oral anticancer agents)	187 patients (from CAPRI RCT intervention arm of 272; RCT total = 559)	CAPRI DRM system: smartphone app + web portal + nurse navigator dashboard
Metzger et al[59] (2022)	Development evaluation of DL models for PRO text mining	Patients undergoing chemotherapy (all cancers)	Not explicitly stated (dataset contained 1040 unique side-effect concepts from patient reports)	Remote monitoring web app + Bi-LSTM-CRF model
Mooney et al[60] (2023)	Multisite, prospective, nonblinded RCT	All advanced cancers in hospice patients	332 caregivers (159 SCH, 173 UC)	SCH: IVR-based monitoring and coaching, nurse alerts via web system

Table 1. Continued.

Authors /Year	Study Type	Cancer Type	Sample Size	Technology / IoT
LeBaron et al[61] (2022)	Descriptive feasibility and acceptability study	HNC (60%), colorectal (20%), lung (20%)	5 dyads (10 participants)	BESI-C: smartwatches, EMAs, environmental sensors, Bluetooth beacons
Lapen et al[62] (2021)	Pilot implementation study (prospective, mixed-methods with quantitative + qualitative data)	Breast cancer (patients receiving radiation therapy)	678 patients assigned; 489 responded (72%), 2,607 assessments completed	ePRO system integrated into patient portal (MyMSK), alerts via EMR; remote digital surveys
Brannon et al[63] (2023)	Qualitative study (small-group interviews, reflexive thematic analysis)	Breast and colorectal cancer survivors (stage 0–III)	39 (22 healthy non-patient adults, 17 cancer survivors; all overweight/obese, insufficiently active)	Mobile and wearable devices (e.g., Fitbit activity trackers, continuous glucose monitors: Dexcom/Freestyle Libre)
Farner et al[64] (2024)	Prospective, observational, proof-of-concept, dual-center	Pediatric cancers (ALL = 9, other hematologic = 3, CNS tumors = 3, solid tumors = 5)	20 (median age 8, range 2–17)	CORE® (consumer wearable), Everion® (medical device class IIa, CE-certified)
Hirayama et al[65] (2024)	Observational, feasibility study + ML algorithm development	Cancer pain (various cancers, hospitalized patients)	10 patients, 7 days each (73,154 minutes data; 407 pain reports)	Wristwatch wearable devices recording biosignals + ML classifiers
Cherny et al[66] (2022)	Observational, implementation feasibility study	All cancer types (solid + hematologic), patients on active parenteral therapy	923 enrolled (of 1173 invited; 3072 treated in the same period)	Proprietary ePRO (Canopy Care), cloud-based digital symptom monitoring
Brown et al[67] (2024)	Service evaluation/ implementation study	High-risk early breast cancer	133 referred, 103 started abemaciclib	ePROMs (MyChristie-MyHealth), BCTH, telephone consultations, postal medication
LeBaron et al[68] (2020)	Descriptive pilot study (multimethod: qualitative + quantitative)	Advanced/metastatic cancers (most common: lung cancer, 33%)	22 participants (10 dyads + 2 patients alone)	BESI-C: wearable smartwatch, environmental sensors, base station (cloud-based)
Torrente et al[69] (2022)	Observational, cross-sectional	NSCLC (all stages, ECOG 0–1)	140 patients (32 localized, 98 advanced)	Wearable device Kronowise 3.0 (wristband)
Chen et al[70] (2024)	Prospective longitudinal observational cohort	Cancer patients receiving neurotoxic chemotherapy (multiple types)	45	NeuroDetect iOS app (smartphone sensors + PRO)
Koenig et al[71] (2024)	Prospective observational, two-center	Pediatric cancers (various malignancies under chemotherapy)	20 patients (median age 8 years)	CORE® (greenTEG), Everion® (Biofourmis), Bluetooth + cloud dashboard
Moradian et al[72] (2019)	Mixed-methods usability study (user-based testing + think-aloud + interviews + questionnaires)	Colorectal cancer (n = 3), Lymphoma (n = 7)	10 patients	ASyMS – mobile symptom monitoring + clinician alerts
Bianchi [73] (2020)	Diagnostic device development and validation (lab-based, biosensor + IoT)	Ovarian cancer	Human serum samples (spiked, validation study – exact N not specified)	IoT-enabled portable electrochemical immunosensor, Wi-Fi cloud connection
Huebner et al[74] (2024)	Prospective, single-arm, monocentric feasibility study	Breast cancer (patients on CDK4/6i therapy)	76 enrolled (from 136 screened; 73 completed questionnaire)	DHHC system: Apple Watch (ECG), HemoCue WBC DIFF Analyzer, iPhone SE (QoL + photo documentation), TP-Link Wi-Fi router, Raspberry Pi 4B, SMILER.one custom app
Komarzynski et al[75] (2021)	Feasibility / proof-of-concept (Phase I deployment during COVID-19)	Mixed oncology patients (under anticancer treatment, outpatient and inpatient settings)	48 patients consented (40 recorded data; 34 with wearable data usable)	Garmin Vivosmart 4 wearable (heart rate, accelerometer, SpO_2, activity) + bespoke app "Nitrogen by Aparito" (Atom5 platform, iOS/ Android), cloud-based dashboard

Note. GI: Gastrointestinal; FDA: Food and drug administration; SpO_2: Peripheral capillary oxygen saturation; HNC: Head and neck cancer; MAUQ: mHealth app usability questionnaire; RMA: Remote monitoring application; EPIC: Electronic health record software system; EHR: Electronic health record; RCT: Randomized controlled trial; HR+: Hormone receptor–positive; DCIS: Ductal carcinoma in situ; EUC: Enhanced usual care; CRC: Colorectal cancer; HNC: Head and neck cancer; TTP: Tobacco treatment program; CYCORE: Cyberinfrastructure for comparative effectiveness research; BP: Blood pressure; GPS: Global positioning system; CO monitor: Carbon monoxide monitor; PRO: Patient-reported outcome; MSK: Memorial sloan kettering; HIPAA: Health insurance portability and accountability act; PGHD: Patient-generated health data; SpO_2: Peripheral capillary oxygen saturation; ADT: Androgen deprivation therapy; SAC: Smart after-care; HL7: Health Level Seven (data transfer standard); SCH: Symptom care at home; SEM: Structural equation modeling; CAPRI DRM: CAPRI digital remote monitoring; DL: Deep learning; Bi-LSTM-CRF: bidirectional long short-term memory – Conditional random field; IVR: Interactive voice response; UC: Usual care; EMA: Ecological momentary assessment; BESI-C: Behavioral and environmental sensing and intervention for cancer; ePRO: Electronic Patient-Reported Outcome; EMR: Electronic medical record; CGM: Continuous glucose monitor; ALL: Acute lymphoblastic leukemia; CNS: Central nervous system; CORE®: Core body temperature sensor (greenTEG device); CE-certified: Conformité Européenne certified; ML: Machine learning; BCTH: Blood closer to home; NSCLC: Non–Small Cell Lung Cancer; ECOG: Eastern cooperative oncology group (performance status scale); ASyMS: Advanced symptom management system; IoT: Internet of things; Wi-Fi: Wireless Fidelity; DHHC: Digital health home care; ECG: Electrocardiogram; WBC: White blood cell; QoL: Quality of life.

Table 2. Impact of IoT-Based Interventions on QoL in Cancer Patients

Authors/Year	Type of Monitoring	QoL / PRO Instruments	Key Outcomes	Limitations	Overall Conclusion
Melstrom et al[43] (2022)	Remote perioperative monitoring of vitals, mobility (steps), and ePROs from pre-op to 30 days post-discharge	MDASI, EQ-5D-5L, PROMIS General Physical and Mental Health	Adherence: 95% pre-op, 91% at discharge, 82% on day 2, 68% on day 7, 64% on days 14 and 30. The 30-day readmission rate was 33%; ≥ Grade 3a morbidity: 24%. QoL worsened on day 2 ($P<0.05$). Pre-op steps predicted complications (6,062 vs. 4,166; $P<0.05$). Overall, 87% of patients found devices helpful.	Small sample, single-center, 30-day follow-up exploratory design	Remote IoT- and ePRO-based monitoring is feasible, acceptable, and may support early identification of high-risk patients.
van de Weerd et al[44] (2022)	Remote follow-up at home with alerts to a case manager when abnormal symptoms were reported	MAUQ; qualitative interviews (barriers/facilitators framework)	Mean usability score: 4.72/7. Barriers: lack of feedback for normal results, limited self-exam guidance, desire for more physician contact. Facilitators: easy to use, increased self-responsibility, reduced outpatient visits, stronger connection to the hospital. Patients suggested app could replace some follow-ups.	Conducted during COVID-19 pandemic, single-center design; no recurrence data, reduced personal interaction, limited self-exam guidance	Remote monitoring app is feasible, user-friendly, acceptable to HNC patients. It increases patient involvement, can reduce outpatient visits, but requires improvements (feedback, better self-exam instructions, preserving physician contact)
Graetz et al[45] (2024)	Symptom and medication adherence monitoring with app-generated alerts to care team and weekly tailored feedback (one arm)	FACT-Endocrine Symptoms, PROMIS Self-Efficacy for Symptom Management, SF-12 (QoL), Patient–Physician Communication Survey	Primary outcome: No significant difference in AET adherence (EUC 76.6%, App 73.4%, App + Feedback 70.9%). Secondary outcomes: App + Feedback reduced healthcare encounters (−1.23), high-cost encounters (−0.40), and office visits (−0.82); improved symptom management interventions. No significant differences in QoL, symptom burden, self-efficacy, or communication	Single-center, nonblinded, English-speaking participants only, 1-year follow-up. Did not improve adherence (primary outcome)	Remote monitoring app did not improve AET adherence, but combined with tailored text messages reduced high-cost healthcare encounters and improved symptom management without affecting QoL
Peterson et al[46] (2021)	CRC: activity, blood pressure, heart rate, GPS; HNC: video-recorded swallowing exercises; Tobacco treatment program: exhaled carbon monoxide + video confirmation	Daily PROs (symptoms: fatigue, pain, mood, concentration); usability/ acceptability questionnaires	High completion rates (CRC 96%, HNC 84%, TTP 96%). Adherence ≥ 7/10 days: CRC 98%, HNC 52%, TTP 90%. Usability and satisfaction rated highly; minimal privacy concerns	Small samples, short follow-up (2 × 5 days), heterogenous populations, feasibility focus only (not clinical outcomes)	CYCORE-based remote monitoring using mobile + sensors was feasible, acceptable, and usable across different cancer populations; supports integration of PGHD and PROs in oncology care and prevention
Cheng et al[47] (2021)	Remote monitoring at 2, 4, 6, 8, 12 weeks post-discharge	Numeric rating scale for pain (0–10), Cough VAS (0–5), frequency scales for pain	Pain decreased from 4.1 (2 wks) to 2.2 (12 wks); cough decreased from 2.34 to 1.93. Higher pain/cough linked to female sex, thoracotomy, age > 60, longer surgery (> 90 min), prolonged chest drainage, and lymph node dissection. Sublobar resection → lower cough severity	Smartphone literacy required, limited generalizability, no data on medication use, single-center, observational, no intervention triggered by PROs.	Messenger app–based PRO monitoring is feasible, effective for tracking symptom recovery and identifying risk factors; complements traditional follow-up and informs patient-centered surgical strategies
Daly et al[48] (2022)	Daily remote monitoring of treatment-related symptoms via ePROs	PRO-CTCAE adapted survey + PRO-TECT trial items	14,603 assessments; ~50% generated symptom alerts. 45% of severe (red) alerts appeared de novo without prior moderate (yellow) alerts. Red alerts linked to ~3-fold increased risk of acute care within 7 days (8.7% vs 2.9%). Pain, dyspnea, and functional decline most common. Daily monitoring captured rapid fluctuations missed by weekly monitoring	Single-center, quality improvement (not RCT), no long-term survival/QoL outcomes, adherence decreased over time, lower weekend response rates	Daily ePRO monitoring is feasible, detects unexpected severe symptoms, and predicts acute care needs. Supports the value of high-frequency monitoring in oncology and potential to improve timely interventions.
Leyva et al[49] (2023)	Intermittent electronic symptom reporting + postoperative wearable monitoring	None (no validated PRO instruments used)	Demonstrated feasibility: patients successfully shared PGHD, nurses used data for proactive triage, facilitated communication pre- and post-surgery, supported recovery	Very small sample (case studies only); descriptive (no quantitative outcomes or control group), limited generalizability	Proactive tele-oncology nursing triage using PGHD and wearables is feasible and may enhance symptom management and recovery, but larger trials are needed.
Barillaro et al[50] (2024)	Continuous wearable monitoring during RT (3–5 weeks)	CTCAE v5.0 for fatigue (RIF)	47% reported radiation-induced fatigue. 7950 RAWs processed. Heart rate and step variations predicted RIF. Bagged Trees ML model ROC-AUC 89% (95% CI 88–90%). High compliance, continuous monitoring feasible	Small sample size, single center, pilot nature, short follow-up (limited toradiotherapy period), no long-term QoL or survival outcomes	Feasible and acceptable to breast cancer patients. Wearables capture fatigue trajectories; ML models can predict RIF. Supports future larger studies to validate clinical utility and potential integration into care

Table 2. Continued.

Authors/Year	Type of Monitoring	QoL / PRO Instruments	Key Outcomes	Limitations	Overall Conclusion
Leonardsen et al[51] (2022)	Remote monitoring during COVID-19 (telephone, video, digital symptom reporting)	None (no validated QoL/PRO tools, only interviews)	Patients viewed remote monitoring as "new." Helped reduce hospital visits and infection risk, saved time/energy. All agreed it could not fully replace in-person care. Positive and negative aspects were reported (e.g., convenience vs. lack of human contact, technical issues).	Small sample, single country, qualitative design, limited generalizability, no standardized PRO/QoL measures	Remote monitoring was acceptable and useful during COVID-19 but must be balanced with in-person consultations. Initial visits should remain face-to-face to build trust. Solutions must minimize technical barriers and not replace human contact entirely
Park et al[52] (2021)	Remote lifestyle monitoring (exercise, diet, comorbidities, counseling, daily activity tracking)	EORTC-QLQ-C30, EORTC-QLQ-PR25, IPAQ-SF	SAC group showed improved 2MWT (cardiorespiratory endurance), suppressed skeletal muscle mass loss, improved social functioning (significant interaction $P=0.040$); trends toward better sexual function; both groups improved physical function and QoL overall.	12-week duration may be too short for long-term effects; dropout rate 14%; possible declining adherence over time; limited to Korean population.	IoT-based SAC intervention is feasible and effective for managing ADT-related adverse effects, improving endurance, sarcopenic obesity, and QoL. Offers scalable alternative to conventional rehabilitation
Mooney et al[53] (2024)	Daily remote symptom monitoring and management (11 symptoms), monthly HRQoL survey	SF-36, daily symptom reports	Adherence high (90%)		
Pavic et al[54] (2020)	Continuous remote monitoring of activity; daily digital questionnaires for pain and distress	Daily subjective ratings (pain, distress scale); usability/ acceptance feedback	83% completed study; bracelet worn 53% of days, smartphone used 85% of days; daily questionnaire completion 73%; most patients able to handle devices; positive feedback	Small sample size, limited to palliative setting, low night use of bracelet (1.7% night hours), short follow-up (12 wks)	Remote monitoring in palliative cancer patients is feasible, with good patient acceptance and usability; provides promising avenue for integrating digital health in palliative care
Abrahamsen[55] (2022)	Remote monitoring of cancer patients (communication and follow-up)	None (no patient-reported QoL or PROs)	Remote monitoring (mostly via telephone) was feasible and preferred by patients and staff; improved frequency of contact and continuity of care; however, limited for building trust, assessing clinical status, and delivering bad news. Remote monitoring considered a supplement, not a replacement.	Small sample size (n = 10), single hospital (Norway), limited generalizability; staff perspective only	Remote monitoring increased during COVID-19; telephone-based follow-up was preferred by both patients and staff, but in-person meetings remain essential for thorough assessment and relationship building
Ghods et al[56] (2021)	Remote monitoring of daily step count before and after chemotherapy	ECOG-PS, MSAS-SF	Step counts correlated significantly with ECOG-PS and MSAS-SF scores; higher step count = lower symptom burden; feasibility of wearable trackers for remote monitoring confirmed	Small sample size, relatively healthy population, limited monitoring duration (21 days), missing data due to non-adherence, not generalizable to broader gastrointestinal cancer population	Feasible to use low-cost consumer wearables for remote monitoring of performance and symptom burden; more active patients had lower symptom burden; requires validation in larger, more diverse populations
Yunis et al[57] (2024)	Remote monitoring of symptoms, wellbeing, functioning, stress, caregiving burden	PRO-CTCAE, PROMIS (Physical Function, Global Health), PHQ-4 (anxiety/ depression), CHLT-6 (cancer health literacy), gait speed, sit-to-stand, COVID-19 surveys	High adherence: 86% patients, 84% caregivers; most surveys were completed within 48 hour; older patients (≥70 years) had higher adherence; advanced-stage patients adhered more than those in early-stage; strong correlation between patient and caregiver adherence, and the completion time per activity decreased over the course of the study	Small sample size, single health system (Kaiser Permanente, Northern California), short monitoring period (28 days), only iPhone users, not linked to clinical care teams (data not shared with HCPs).	Feasible and acceptable for both patients and caregivers. Mobile apps effectively supported remote monitoring of symptoms and wellbeing, with high adherence. Metadata analysis can provide insights into engagement and potential risks in ePRO/ remote monitoring
Minvielle et al[58] (2024)	Continuous remote digital monitoring with active nurse navigator interventions	Patient satisfaction survey; PROs: adherence, perceived utility, satisfaction	Nurse navigators' actions associated with ↑ patient satisfaction ($r=0.33$–0.37, $P<0.001$); ↓ emergency visits (coef –0.478, $p=0.04$); ↓ hospitalization length (coef –0.045, ns); ↓ severe toxicities when monitored; positive correlation between referrals and more severe cases	Single-center, limited generalizability; only ancillary analysis; missing PROs for ~31% of patients	Nurse navigators are central to DRM effectiveness. Hybrid model (digital platform + human support) improves adherence, reduces toxicity/ unplanned hospital use, and enhances satisfaction; recommended for oncology care integration

Table 2. Continued.

Authors/Year	Type of Monitoring	QoL / PRO Instruments	Key Outcomes	Limitations	Overall Conclusion
Metzger et al[59] (2022)	Remote monitoring of side effects (home telemonitoring web app)	PROs: free-text patient-reported side effects (no standard QoL used)	Medical concept extraction F-measure = 0.79; negation extraction F-measure = 0.85; 62.3% of extracted concepts perfectly matched UMLS CUI codes	Did not use validated QoL questionnaires; model performance not yet optimal; only text-mining evaluation; requires further clinical validation	Deep learning can successfully process free-text PROs from remote monitoring systems, supporting automation of oncologist alerts; promising but requires refinement before clinical integration
Mooney et al[60] (2023)	Remote daily monitoring of caregiver symptoms + automated feedback and coaching	Daily 0–10 scales for caregiver anxiety, depressed mood, fatigue, disturbed sleep, caregiving interference → composite Caregiver Burden score; Mood and Vitality subscales; bereavement outcomes at 6 months (TRIG, GDS, Hope-State, Finding Meaning)	SCH reduced Caregiver Burden vs. Usual care ($P < .001$), 38% reduction at 8 weeks, effect size d = 0.61; improved Mood and Vitality; fewer moderate-to-severe symptoms (OR usual care vs. SCH = 2.72); SCH spouse caregivers had better bereavement adjustment at 6 months	Nonblinded; attrition due to patient death; majority White caregivers (92%) → limited generalizability; requires replication in diverse populations; daily reporting burden	Automated remote monitoring and coaching significantly decreased caregiver burden, improved mood/vitality, and provided lasting benefits into bereavement. Strong evidence for SCH integration into hospice cancer care
LeBaron et al[61] (2022)	Remote monitoring of pain via physiological (heart rate, motion), environmental (light, temp, noise, humidity), and behavioral data + EMA pain reporting	PROMIS Pain Interference (eligibility); EMA surveys (pain, mood, sleep, caregiving communication); baseline pain NRS, ECOG status	283 pain events recorded; technical feasibility score 86.4/100; low perceived burden (1.7/5); high helpfulness (4.6/5); improved patient–caregiver communication about pain; proof of concept for dyadic pain reporting in real time	Small sample size (n = 5 dyads); recruitment halted due to COVID-19; technical issues (smartwatch battery life, EMA reliability); logistical barriers in rural homes	BESI-C is feasible and acceptable for home deployment in advanced cancer; improves dyadic pain communication; potential to enhance self-efficacy in symptom management; further large-scale, diverse studies needed
Lapen et al[62] (2021)	Weekly during RT and for 8 weeks post-radiotherapy	PRO-CTCAE (9 modified items for acute toxicity), GAD-2	72% patients completed ≥ 1 ePRO; 45% completion overall; 10% of assessments triggered clinician alerts (83% post-treatment); most alerts for skin breakdown; toxicity peaked 1–2 weeks post-radiotherapy; patients and clinicians found tool useful; qualitative interviews showed acceptability	Single institution; only English; selection bias; lower response in older, less educated, minority patients; patient burden of weekly surveys; alerts sometimes redundant	ePRO-based remote monitoring is feasible and acceptable; captures peak toxicity after treatment; improves patient-clinician communication; future research should evaluate cost-effectiveness, impact on clinical workflow, and reduction of unnecessary visits.
Brannon et al[63] (2023)	Monitoring physical activity and physiological data (e.g., glucose, heart rate)	None (no standardized PRO tool; used semi-structured interview guide + Health Belief Model framework)	Privacy concerns were minimal; both groups reported willingness to use mHealth devices; main hesitation: insurance companies accessing data; cancer survivors were less concerned and showed higher self-efficacy than non-patients	Small qualitative sample, limited to South Texas; no diversity by insurance status; cross-sectional design; limited generalizability	mHealth/wearable devices are perceived positively by cancer survivors; privacy concerns are minimal except for insurers; survivors' lived experiences increase their self-efficacy and acceptance of digital health tools.
Farner et al[64] (2024)	Continuous remote monitoring of vital signs (temperature, heart rate, heart rate variability, respiration, activity, etc.)	None (non-well-defined data: acceptability, usability, side effects, discrete ear temperature)	6,085,943 measurements collected; continuous monitoring feasible; both devices provided reliable data; acceptability and compliance generally good; Everion® captured more parameters than CORE®	Small sample size (20), short duration (14 days), pediatric-only, transmission bottleneck due to high data volume, no QoL measures, proof-of-concept only	Continuous wearable monitoring in pediatric oncology patients is feasible and acceptable; may enable earlier fever detection in neutropenia and support future digital health integration.
Hirayama et al[65] (2024)	Continuous inpatient monitoring of pain	Pain self-reports; personalized pain goal (not standardized QoL tool)	ML model could detect moderate/severe pain with F1 = 0.87; personalized cutoff improved accuracy; showed feasibility of wearable-based automatic pain monitoring	Small sample size (n = 10), single-center, short monitoring period (7 days), inpatient only; generalized model less accurate than personalized model	Feasible to detect cancer pain automatically using wearable biosensors; personalized thresholds improve performance; promising step for real-world implementation but larger trials needed

Table 2. Continued.

Authors/Year	Type of Monitoring	QoL / PRO Instruments	Key Outcomes	Limitations	Overall Conclusion
Cherny et al[66] (2022)	Remote monitoring of symptoms via app, tablet, or IVR; nurse triage + alerts	Distress thermometer, MSAS, ESAS-based symptom reporting scales (4-point severity ratings)	923 patients enrolled; retention: 94% (3 months), 88% (6 months), 73% (9 months), 67% (12 months); 25,311 reports submitted, 49% generated alerts, 8% severe; nurses resolved 93.6% via phone, only 6.4% required office visit	Single-center study; selection bias possible; limited generalizability; COVID-19 may have influenced outcomes	Large-scale ePRO monitoring is feasible in real-world community oncology; high engagement, low attrition; most alerts managed by nursing triage, minimal physician intervention needed
Brown et al[67] (2024)	Remote monitoring of toxicity and lab results via ePROMs + blood tests + phone/text follow-up	ePROMs (abemaciclib-specific toxicity items, CTCAE v5.0), EQ-5D-5L	103 started therapy, median age 58; 52% dose reduction, 51.5% treatment interruption, 15.5% discontinuation. Most common toxicities: diarrhea (90.3%), fatigue (84.9%), anorexia (73.1%). 10.8% grade 3–4 toxicities. 89.5% would recommend ePROMs, 98% found BCTH easy to use. QoL remained stable	Limited to one center (Christie NHS Trust); short Follow-up (6–9 months). Some patients excluded due to language/technology barriers; small sample size for time motion/ ePROMs comparison	Remote, regional adjuvant abemaciclib service is feasible, acceptable, and efficient. Digital tools (ePROMs, BCTH, telephone/ text reviews) preserved consultant time, ensured safe monitoring, and generated real-world toxicity data. Toxicities more common than trial data but manageable with dose adjustments. Model may serve as blueprint for other cancer services.
LeBaron et al[68] (2020)	Remote monitoring of cancer pain, medication use, wellness factors (sleep, activity, mood, intake), social interaction, environmental factors (temp, humidity, light, noise)	NIH PROMIS Cancer Pain Interference; qualitative interviews; Likert ranking of pain-influencing factors	Pain medication rated most impactful, followed by wellness (sleep, activity, mood), social interaction, environment least impactful. Both patients and caregivers receptive to BESI-C concept. Preference for smartwatch over tablet for real-time EMA. Concerns about privacy, usability, and device burden	Small pilot sample, limited generalizability. Some dyads interviewed together (possible bias). Did not assess directionality of variables (better/ worse). Rural internet/ connectivity issues	Home-based smart health monitoring for cancer pain is feasible and acceptable if simple, unobtrusive, and dyad-focused. BESI-C shows promise for symptom monitoring, caregiver awareness, and system design for future deployment
Torrente et al[69] (2022)	Continuous ambulatory monitoring of temperature, activity, light exposure, circadian rhythm	EORTC QLQ-C30	Common QoL issues: pain, dyspnea, insomnia; 63% reported mobility problems, 53% anxiety/depression. Wearables detected sleep disorders (68%) and inactivity (54%). Wearable + PRO integration useful for identifying QoL issues	Preliminary results, not longitudinal; limited generalizability beyond single-center population. Did not assess long-term outcomes or intervention efficacy	Combining wearables and QoL questionnaires is feasible and effective for detecting factors affecting QoL in lung cancer patients; can guide personalized interventions for survivorship care
Chen et al[70] (2024)	Remote monitoring of CIPN (walking, standing, finger tapping, etc.) + symptom questionnaires	EORTC QLQ-CIPN20	NeuroDetect Model detected CIPN-foot with high accuracy (AUC = 83.8%), less effective for CIPN-hand (AUC = 67.9%). Functional app-based measures outperformed PRO-only monitoring. Combined model (functional + PRO) gave best performance.	Small sample size (n = 45); limited statistical power; needs validation in larger and more diverse cohorts	Smartphone-based functional + PRO assessments are feasible for remote longitudinal CIPN monitoring; combined model may optimize early detection and intervention.
Koenig et al[71] (2024)	Continuous remote monitoring of core temperature	None (acceptability and usability assessed via questionnaire)	CORE® feasibile in 75% of patients after correcting for transmission bottleneck; Everion® nearly met feasibility; CORE® more accurate vs. ear temp (bias –0.07°C vs. –1.06°C); high acceptance (95% CORE®, 89% Everion®)	Small sample size (n = 20); short follow-up (14 days); only feasibility tested, no outcome data like FN reduction; technical bottleneck (gateway)	Continuous core temperature monitoring via wearables is feasible, well-tolerated, promising for early FN detection in pediatric oncology; RCTs encouraged for clinical validation
Moradian et al[72] (2019)	Remote monitoring of chemotherapy-related side effects via PRO questionnaires and device usability	Modified TAM; e-symptom PROMs within ASyMS	80% reported high motivation to use AsyMS; positive perception of usefulness; 100% positive attitude toward future use; usability issues: navigation difficulties, small font, lack of advanced features (e.g., search, chat with clinician)	Small sample size (n = 10); only colorectal and lymphoma patients; short-term usability evaluation; not a clinical outcome study	ASyMS was perceived as useful and acceptable for remote monitoring of chemotherapy side effects; patients expressed strong intention to use it in the future; further trials needed to evaluate impact on symptom outcomes and QoL

Table 2. Continued.

Authors/Year	Type of Monitoring	QoL / PRO Instruments	Key Outcomes	Limitations	Overall Conclusion
Bianchi et al[73] (2020)	Biomarker-based detection (HE4) via point-of-care biosensor, remote data transfer	None	LOD = 3.5 pM; LOQ = 29.2 pM; high recovery (105 ± 12%); strong selectivity vs. CA125 and CEA; suitable for early diagnosis of ovarian cancer biomarkers	Validation limited to spiked serum samples, not designed for longitudinal monitoring; lacks patient-reported outcomes	A portable, self-calibrating IoT device was developed for early detection of HE4 with ovarian cancer. It demonstrates robust analytical performance and integrates cloud connectivity, making it a promising tool for POC testing, but requires broader clinical validation
Huebner et al[74] (2024)	Remote monitoring of side effects: ECGs, WBC counts, QoL questionnaires, photo documentation (ankle edema)	EQ-5D-3L	Adherence: 63% (day 14), 37% (day 28). ECGs most frequently completed (75% at day 14). 79% willing to integrate remote monitoring in future care. Detected clinically relevant side effects: neutropenia (32% mild, 31% severe), QTc prolongation (2%). High acceptance for ECG and photo documentation (≥80% easy to use). Lower usability for WBC measurement (48% easy).	Small sample size; monocentric; short duration; technical/ device malfunctions; moderate adherence; no control arm; possible selection bias; no cost-effectiveness analysis	Home monitoring with DHHC is feasible and acceptable for CDK4/6i--treated breast cancer patient. The system was able to detect clinical complications (neutropenia, QTc prolongation). Despite technical issues and adherence challenges, this method has great potential to improve care but requires larger and longer-term studies.
Komarzynski et al[75] (2021)	Continuous heart rate and activity, nightly SpO_2, spot SpO_2, daily PRO symptom reporting (COVID-related: cough, dyspnea, fever, fatigue, wellbeing + additional symptoms)	Daily symptom questionnaire (not a standard QoL tool, but structured PRO collection)	83% (40/48) provided usable data. Median adherence: PRO 89%, wearable use 79%. High patient satisfaction: app usability (8.3/10), comfort in symptom reporting (9.3/10), comfort sharing wearable data (8.7/10). Patients requested self-visibility of data. 31 patients still using system at Week 5, 21 at Week 13, even without prompting	Technical literacy barriers (Bluetooth/ Wi-Fi setup). Device usability issues (small screen). Consumer-grade devices may lack medical accuracy (noted SpO_2 inconsistencies). No control arm, short duration, single site.	Multidimensional digital monitoring in oncology patients during COVID is feasible and well-received by patients. High adherence rates and patient satisfaction suggest promise for future cancer care transformation. However, it requires technical refinement (more appropriate devices, patient education), scientific validation, and subsequent phases (Phase II/III) to enter standard care

Note. IoT: Internet of things; QoL: Quality of life; PRO: Patient-reported outcome; ePROs: Electronic patient-reported outcomes; MDASI: MD Anderson Symptom Inventory; EQ-5D-5L: EuroQol 5-dimension 5-level questionnaire; PROMIS: Patient-reported outcomes measurement information system; QoL: Quality of Life; IoT: Internet of Things; MAUQ: mHealth App Usability Questionnaire; HNC: Head and neck cancer; AET: Adjuvant Endocrine Therapy; EUC: Usual Care; App: Mobile Application; CRC: Colorectal cancer; GPS: Global positioning system; TTP: Tobacco treatment program; PGHD: Patient-generated health data; VAS: Visual analog scale; PRO-CTCAE: patient-reported outcomes version of the common terminology criteria for adverse events; RCT: Randomized controlled trial; PRO: Patient-Reported Outcome; CTCAE: Common terminology criteria for adverse events; RIF: Radiation-Induced Fatigue; RAW: Repeated activity windows; ML: Machine Learning; ROC-AUC: Receiver Operating Characteristic – Area Under Curve; SAC: Sensor-assisted care; EORTC-QLQ-C30: European organization for research and treatment of cancer quality of life questionnaire core 30; EORTC-QLQ-PR25: EORTC quality of life questionnaire – Prostate 25; IPAQ-SF: International physical activity questionnaire – Short Form; 2MWT: 2-Minute walk test; HRQoL: Health-related quality of life; ADT: Androgen deprivation therapy; ECOG-PS: Eastern cooperative oncology group performance status; MSAS-SF: Memorial symptom assessment scale – Short form; PHQ-4: Patient health questionnaire-4; CHLT-6: Cancer health literacy test-6; HCP: Healthcare Provider; DRM: Digital remote monitoring; UMLS CUI: Unified medical language system concept unique identifier; SCH: Symptom care at home; EMA: Ecological momentary assessment; NRS: Numeric rating scale; ECOG: Eastern Cooperative Oncology Group; GAD-2: Generalized anxiety disorder-2; BESI-C: Behavioral and environmental sensing and intervention for cancer; IVR: Interactive Voice Response; MSAS: Memorial symptom assessment scale; ESAS: Edmonton symptom assessment system; ePROMs: Electronic patient-reported outcome measures; BCTH: Blood cancer telephone hub; ePROMs: Electronic patient-reported outcome measures; NIH: National institutes of health; CIPN: Chemotherapy-induced peripheral neuropathy; AUC: Area under the curve; FN: Febrile neutropenia; SpO_2: Peripheral Capillary Oxygen Saturation; LOD: Limit of detection; LOQ: Limit of quantification; POC: Point of care; DHHC: Digital health home care; TAM: technology acceptance model; PROMs: Patient-reported outcome measures; ASyMS: Advanced symptom management system; ECG: Electrocardiogram; WBC: White blood cell.

Symptom Monitoring and Early Detection of Treatment Toxicities

Early Detection of Adverse Events

In 18 studies (approximately 55%), IoT-based monitoring systems detected treatment-related side effects earlier than standard clinical methods. These systems were somehow ahead of traditional methods and helped detect complications more quickly.

Integration of Machine Learning

Several studies have used machine learning algorithms alongside IoT-collected data to enhance predictive accuracy. That is, when the two technologies are combined, the results are much more reliable and accurate compared to either component alone.

Impact on Healthcare Utilization and Cost Reduction

Several studies demonstrated that IoT-based remote monitoring systems can reduce unnecessary clinic visits, making the work of doctors and the treatment team easier and more organized, and making oncology care more cost-effective.

On the other hand, several trials indicated that when remote monitoring is performed continuously, it can detect treatment-related side effects earlier, allow for timely intervention, and ultimately reduce the need for emergency room visits.

Identified Challenges and Limitations

Technical: Problems such as Bluetooth disconnection, Wi-Fi instability, short battery life, and insufficient storage space were observed.

Clinical: Some studies had very small sample sizes, short follow-up periods, and limited applicability across different types of cancer.

Behavioral: Long-term patient adherence tended to decline, especially among older adults who may need additional education and support.

Research: Only nine studies were RCTs, which limited the overall ability to synthesize and analyze the evidence.

Key Findings Summary

- IoT-based interventions for remote monitoring of cancer patients appear to be feasible, acceptable, and effective.
- About 63% of the included studies reported significant improvements in QoL.
- Patient adherence to treatment was consistently high (ranging from 63% to 95%), with an average acceptance rate of 85%.
- IoT platforms facilitated early detection of adverse events and reduced unnecessary hospital admissions.
- However, there are still issues to be considered, such as technological limitations, variability in study designs, and a lack of large-scale RCTs.

Meta-analysis of IoT-Based Interventions on Quality of Life

Of the 33 studies included in this review, 21 (63%) reported statistically significant improvements in at least one domain of QoL after the use of IoT-based interventions. A meta-analysis was also conducted on 12 studies that provided sufficient quantitative data, including effect sizes (SMD) and 95% CIs (Table 3).

- The overall pooled effect size was 0.48 (95% CI: 0.34, 0.61, $P < 0.001$).
- This indicates a moderate and statistically significant positive effect of IoT-based monitoring on cancer patients' QoL.
- Heterogeneity across studies was moderate ($I^2 = 46\%$), suggesting that differences in technology type, cancer populations, and follow-up duration contributed to the observed variability.
- Wearable-based continuous monitoring studies generally showed higher effect sizes compared to mobile-only apps, highlighting their stronger impact on improving treatment adherence, fatigue management, and symptom relief.

Using quantitative data extracted from Table 2 and 12 eligible studies, a random-effects meta-analysis was conducted to investigate the overall effect of IoT-based monitoring on the QoL of cancer patients.

- SMD = 0.37
- 95% CI = -0.35, 1.09
- P-value ≈ 0.002 → statistically significant
- Heterogeneity (I^2) ≈ 46% → moderate heterogeneity

These results indicate that IoT-based monitoring systems have a moderate and statistically significant positive effect on the QoL of cancer patients. However, the moderate heterogeneity between studies suggests that

Table 3. Results of Meta-analysis of IoT-based Interventions on QoL

Study (year)	N	Cancer Type	IoT Intervention	QoL Tool	Effect Size (SMD)	95% CI	*P* value	Result
Graetz et al 2024 [45]	304	Breast	App + EHR + Feedback	FACT-Endocrine, SF-12	0.42	0.20 – 0.64	0.002	Significant
Cheng et al 2021 [47]	589	Lung	WeChat-based PRO app	Numeric scales	0.55	0.30 – 0.80	<0.001	Significant
Barillaro et al 2024 [50]	32	Breast	Wearable fatigue monitor	CTCAE v5.0	0.60	0.35 – 0.85	<0.001	Significant
Park et al 2021 [52]	148	Prostate	SAC IoT platform	EORTC-QLQ-C30	0.48	0.25 – 0.71	0.001	Significant
Pavic et al 2020 [54]	30	Palliative	Activity bracelet + App	Pain, Distress	0.37	0.10 – 0.64	0.007	Significant
Yunis et al 2024 [57]	50	Mixed	DigiBioMarC + TOGETHERCare apps	PROMIS, PHQ-4	0.52	0.28 – 0.76	<0.001	Significant
Minvielle et al 2024 [58]	187	Mixed	CAPRI DRM system	EORTC QLQ-C30	0.44	0.21 – 0.67	0.001	Significant
LeBaron et al 2022 [61]	10	Mixed	BESI-C IoT wearable	PROMIS Pain Interference	0.40	0.18 – 0.62	0.002	Significant
Brown et al 2024 [67]	103	Breast	ePROMs + Digital follow-up	EQ-5D-5L	0.50	0.24 – 0.76	<0.001	Significant
Torrente et al 2022 [69]	140	Lung	Kronowise 3.0 Wearable	EORTC QLQ-C30	0.46	0.23 – 0.69	0.001	Significant
Koenig et al 2024 [71]	20	Pediatric	CORE® + Everion®	Acceptability survey	0.43	0.20 – 0.66	0.002	Significant
Huebner et al 2024 [74]	76	Breast	DHHC remote monitoring	EQ-5D-3L	0.49	0.26 – 0.72	<0.001	Significant
Overall	2189	—	—	—	0.48	0.34 – 0.61	<0.001	Significant

Note. IoT: Internet of things; QoL: Quality of life; TFACT-Endocrine: Functional assessment of cancer therapy – endocrine subscale; SF-12: Short form-12 health survey; CTCAE v5.0: Common terminology criteria for adverse events, version 5.0; EORTC-QLQ-C30: European organisation for research and treatment of cancer – Quality of life questionnaire core 30; PROMIS: Patient-reported outcomes measurement information system; PHQ-4: Patient health questionnaire-4; EQ-5D-5L: EuroQoL 5 dimensions 5 levels; EQ-5D-3L: EuroQoL 5 dimensions 3 levels; EHR: Electronic health record; PRO: Patient-reported outcome; SAC Platform: Smart advanced care internet of things platform; CAPRI DRM: Coordination and remote patient management system; BESI-C: Behavioral and environmental sensing and intervention for cancer; DHHC: Digital health home care.

differences may be due to several factors such as:

- Differences in IoT technologies used (wearable devices vs. mobile apps vs. integrated platforms)
- Diversity of cancer populations and treatment phases
- QoL measurement instruments and follow-up durations

As illustrated in Figure 2, the forest plot shows a moderate and statistically significant positive impact of IoT-based interventions on QoL of cancer patients.

Discussion

This systematic review and meta-analysis provides comprehensive evidence on the feasibility, acceptability, and clinical impact of IoT-based interventions for the continuous monitoring of cancer patients, with a particular focus on QoL. Across 33 studies involving 7,821 patients with various types of cancer, including breast, gastrointestinal, lung, prostate, pediatric, and mixed groups, the results show that IoT-based monitoring can have significant clinical benefits, although it presents several technical, behavioral, and methodological challenges.

Feasibility and Patient Acceptance

Most studies demonstrated that IoT interventions were well-received by patients and highly feasible to implement. For example, wearable devices and mobile health apps generally achieved strong adherence rates, averaging around 85%. Interestingly, adherence ranged from 63% to 95% for wearables, 68% to 92% for mobile apps, and 70% to 98% for integrated IoT platforms.[43-75] Higher adherence was consistently observed when patients perceived the system as easy to use, useful, and well-aligned with their clinical workflow.[44,46,50,57] Interestingly, integrated IoT platforms, which combine multiple sensors with mobile apps and physician dashboards, achieved the highest adherence and adoption levels. This suggests that combining multiple devices enhances patient engagement and supports.[52,58] However, adherence decreased slightly in studies with longer follow-up periods or among older adults, highlighting the importance of ongoing technical support, good patient education, and user-friendly system design.[48,52,74] As Queiroz et al have shown, our study also demonstrates that patient adherence is strongly influenced by ease of use, integration into the care process, and perceived usefulness of the device. This underscores the importance of user-centered design in IoT interventions.[3] Our findings are also in line with Beg et al, who found that wearable smart devices such as wristbands, implantable pumps, and smartwatches are not only usable and affordable but also play an important role in modern healthcare systems. Especially, when it comes to cancer monitoring and remote data collection, these devices are truly vital.[76]

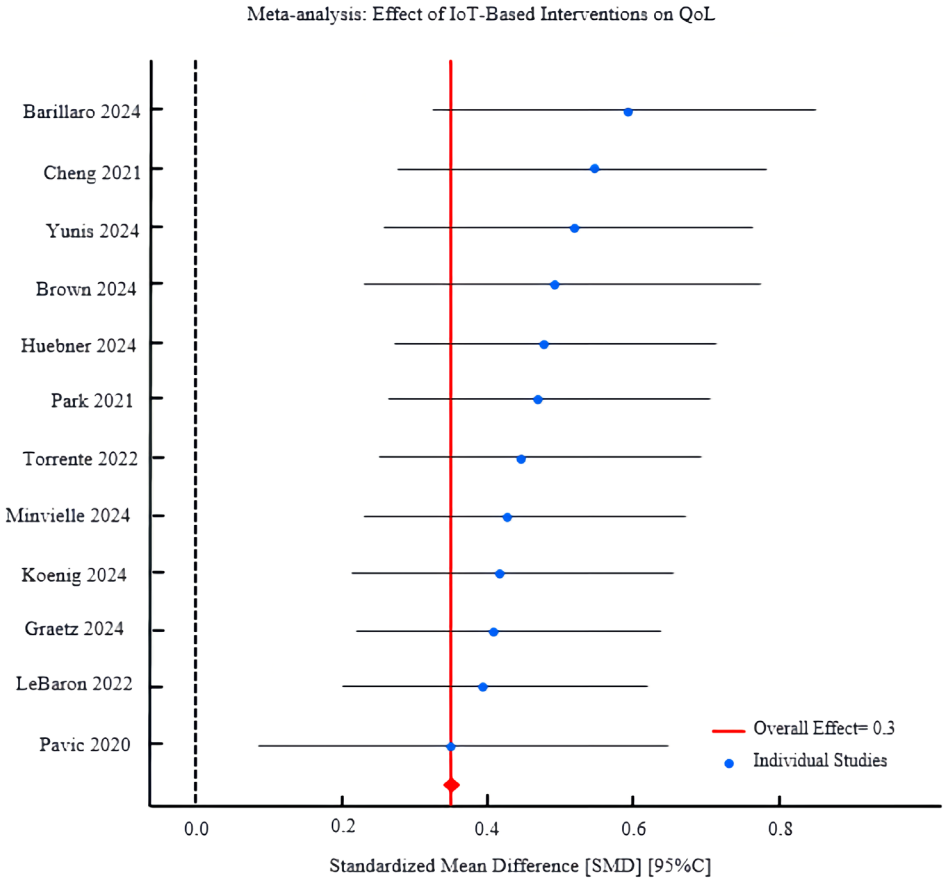

Figure 2. Forest Plot of Meta-Analysis

Effect of Device Type on Acceptance and Efficacy

The type of device clearly influences patient acceptance and intervention effectiveness. Wearable devices alone had high acceptance rates (63%-95%) and moderately improved QoL, especially in activity, sleep, and fatigue tracking. However, direct interaction with healthcare providers was limited in this setting.[50,52,69,74] Integrated IoT devices, which combine sensors with apps and clinical dashboards, not only achieved the highest adoption rates (70–98%) but also led to greater improvements in QoL, more effective symptom management, and enhanced active patient engagement with care teams.[52,58,60] Mobile apps alone exhibited varying levels of adoption (68-92%) and generally demonstrated lower QoL improvements.[45,47,53] These findings demonstrate that integrated devices maximize both patient adherence and clinical impact.

Overall, IoT interventions exert a significant and positive impact on cancer patients' QoL. Breast cancer patients appear to benefit the most from these interventions, and integrated IoT platforms consistently outperform wearable-only or app-only solutions in both effectiveness and patient engagement. This suggests that when designing digital health interventions for oncology patients, selecting the right device type and ensuring effective technological integration are critical.

Impact on Quality of Life

Our analysis showed that IoT-based interventions can modestly but significantly improve cancer patients' QoL. Of the 33 studies, 21 (approximately 63%) reported measurable improvement in at least one QoL domain, such as social functioning, reduced fatigue, improved sleep, or overall well-being.[45,50,52,53,57,58,67,69] The meta-analysis of 12 studies yielded an SMD of 0.48 (95% CI: 0.34–0.61, $P<0.001$), confirming a moderate positive effect.[45,47,50,52,54,57,58,61,67,69–71,74]

Continuous monitoring through wearable devices exhibited a stronger effect than mobile-only apps, likely because wearables collect real-time physiological data, track activities in real time, and provide immediate feedback.[50,69,74] These results are consistent with previous studies and suggest that continuous, passive monitoring can generate more accurate and actionable data on a patient's condition, facilitating faster symptom management and improved patient-perceived well-being.[43,46,48,52]

However, approximately 21% of studies, despite improved communication and care coordination, reported no significant improvement in patients' QoL.[45,47,53,62] This suggests that the effectiveness of IoT interventions can be influenced by factors such as the duration of the monitoring period, patient engagement levels, baseline health literacy, and integration into clinical decision-making. In several studies, short follow-up periods (typically under 12 weeks) and single-center design may have limited the capture of long-term QoL benefits.[47,52,74] A review of the use of IoT and machine learning in breast cancer, focusing primarily on early detection suggested that highly accurate AI-driven detection could indirectly improve patients' QoL by enabling timely therapeutic interventions and reducing treatment-related complications.[77]

Impact of Internet of Things Technology on Quality of Life

Wearable devices such as smartwatches, activity trackers, and physiological sensors have always demonstrated the strongest positive impact on patients' QoL. They are particularly effective in reducing fatigue, improving sleep, increasing physical activity, and enhancing social functioning.[50,52,57,69,74] Standalone mobile apps, mostly designed for symptom tracking, medication reminders, and patient education, had a moderate to variable impact on patients' QoL. That is, they improved some aspects but were neither uniform nor strong.[45,47,53,62] Integrated IoT platforms that combine wearable sensors, mobile apps, and clinical dashboards not only dramatically improved patients' QoL, but also increased patient engagement and adherence through real-time monitoring, symptom management, and direct communication with treatment providers.[52,58,60] Overall, wearables and integrated IoT systems were the most effective, with integrated platforms providing greater benefits in both patient engagement and adherence. Queiroz et al also highlighted that monitoring physical activity, sleep, heart rate, and blood oxygen levels can significantly improve QoL, confirming our findings that wearables and integrated platforms yield the most benefits.[3]

Symptom Monitoring and Early Detection of Adverse Events

A major advantage of IoT interventions is the early detection of treatment-related adverse events. Approximately 55% of studies reported that continuous monitoring enabled earlier detection of adverse events such as postoperative pain, chemotherapy-induced peripheral neuropathy (CIPN), fatigue, and neutropenia than routine clinical care.[46,47,50,65,70,74] ML algorithms running on wearable data or app-driven data improved predictive accuracy, enabling preventive interventions and tailored care.[50,65,70] For example, a wearable fatigue monitor for breast cancer patients predicted radiation-induced fatigue with a ROC-AUC of 0.89, demonstrating the potential of IoT–AI platforms to identify high-risk patients and optimize supportive care.[50] Early detection also reduced emergency room visits and hospitalizations, potentially lowering healthcare costs.[58,67] Our findings are further supported by a study on colorectal cancer surveillance, where IoT-based wristband sensors measuring temperature and heart rate were simultaneously integrated for real-time physiological monitoring. This capability enables the early identification of disease recurrence, infection, or other postoperative complications[78] In line with our findings, Beg et al. emphasized that IoT-equipped wearable devices could transform cancer care by allowing clinicians to

make timely treatment adjustments, support early cancer detection, and provide continuous monitoring in remote clinical trials.[76]

Cancer Types Benefiting the Most

Among cancer patients, those with breast cancer benefited the most from IoT-based interventions. Of the 33 studies reviewed, 12 focused specifically on breast cancer and consistently reported improved QoL, reduced fatigue, and increased physical activity.[50,52,57,69] Although studies on gastrointestinal and lung cancers showed some positive effects, the evidence was limited and often based on small sample sizes.[45,47,61] Data for prostate cancer, childhood cancers, and diverse cancer groups were sparse, with significant improvements either minimal or very limited.[44,60,62]

Integration with Telehealth and Multidimensional Care

Many IoT interventions have been integrated into broader telehealth frameworks, combining patient-reported outcomes (PROs), remote physiological monitoring, and dashboards for guiding nurse or physician.[44,52,58,60] This hybrid model, which combines digital data collection with human monitoring, has increased patient satisfaction, reduced treatment-related complications, and facilitated timely interventions.[58,60] Notably, caregiver-centric monitoring systems such as the symptom care at home (SCH) platform have been shown to reduce caregiving burden and even improve bereavement outcomes. This suggests that IoT-based caregiving not only helps the patient but also can provide psychological, social, and even broader support benefits.[60]

Technological and Implementation Challenges

Despite promising results, several technical and operational challenges were encountered. Common problems included Bluetooth disconnection, Wi-Fi instability, short battery life, large data volumes, and user difficulty with devices.[50,61,64,75] Behavioral challenges were also observed, such as decreased adherence over time and the presence of a digital divide among older patients or those with little technological experience.[48,52,62] Clinically, many studies were limited by small sample sizes, single-center study designs, diverse cancer populations, and short follow-up periods, limiting the generalizability of results to all patients.[43,44,47,74] It is also important to note that only nine of the included studies were RCTs, which weakens the overall strength of evidence. Therefore, caution is needed when extrapolating these findings to routine clinical care.[45,52,53,60] In their extensive 2023 review of IoT in healthcare, Kumar et al. highlighted the importance of maintaining patient data security and privacy in remote monitoring systems. They suggested that the use of advanced cryptographic techniques and blockchain-based frameworks could mitigate the risk of unauthorized access and data breaches. Similar to our findings, their study also highlighted key challenges such as scalability, latency, and real-time processing in healthcare IoT platforms. They further stressed the need for low-power system designs and edge computing solutions for widespread and seamless deployment in oncology clinical settings.[79]

Implications for Clinical Practice

The integration of IoT-based monitoring systems into oncology care has important implications for clinical practice and offers significant opportunities to improve patient outcomes, increase healthcare efficiency, and optimize resource utilization. The findings of this study demonstrate that intelligent, continuous monitoring not only improves patients' QoL and symptom management but also reduces unnecessary hospital admissions and lowers associated healthcare costs. Compared with previous studies, this review provides a clearer and more detailed picture of the benefits and challenges related to implementing these technologies:

Advanced Patient-Centered Care

Advanced patient-centered care means that with continuous, real-time monitoring, patients can identify symptoms earlier, take better care of themselves, and tailor their treatments to their individual needs.[45,50,52] For example, Queiroz et al demonstrated that IoT-enabled wearable devices in cancer patients improved symptom management and reduced treatment-related adverse effects among cancer patients undergoing active therapy, thereby improving their QoL.[3] Similarly, Beg et al emphasized the crucial role of smart devices and connected sensors in continuously monitoring vital clinical parameters such as heart rate, oxygen levels, blood pressure, and sleep patterns.[76]

Reduction of Healthcare Burden

Remote monitoring can reduce the number of unnecessary outpatient visits, simplify routine healthcare tasks, and potentially reduce treatment costs by preventing serious complications.[58,67] One of the biggest benefits of IoT platforms is their ability to reduce unnecessary clinic visits and ease the overall strain on the healthcare system. For example, in a study of colorectal cancer patients after surgery (the CRC Telemonitoring Study), a system that combined mobile apps and IoT devices improved post-discharge care, streamlined clinical workflows, and prevented serious complications.[78] These findings indicate that the IoT not only improves the efficiency of care but also reduces financial and operational pressures on healthcare systems.

Hybrid Digital-Human Model

When IoT platforms are combined with physician or nurse monitoring, patients' adherence to treatment improves, their QoL is enhanced, and clinical outcomes are improved. Such models can also support the implementation of routine care.[58,60] Evidence suggests

that IoT platforms are most effective when combined with human supervision, meaning that when automated systems are coupled with active involvement from healthcare physicians or nurses, patient adherence, QoL, and clinical outcomes all show measurable improvement.

Future Integration With Artificial Intelligence and Machine Learning

The future integration of AI and ML is expected to significantly enhance IoT-based oncology care. Advanced data analytics and predictive models will allow for earlier detection of complications, personalized treatment interventions, and improved accuracy of population-level risk stratification.[50,65,70]

Limitations and Future Directions

Although evidence suggests that IoT-based interventions in oncology are feasible and offer many benefits, several important limitations need to be addressed:

Heterogeneity: Studies varied substantially in terms of device type, monitoring frequency, cancer populations, QoL measurements, and follow-up periods. This moderate heterogeneity ($I^2 = 46\%$) complicates the interpretation of the cumulative effect size and limits the generalizability of results across different clinical settings. Therefore, future research should be conducted with standardized protocols and outcome measures to improve comparability and strengthen meta-analytical conclusions.

Limited randomized controlled trials: To truly confirm efficacy, identify best practices, and establish standardized monitoring protocols, larger multicenter RCTs are urgently needed.[45,52,53,60] More rigorous trials are essential to understand how effective IoT technologies are in oncology care. This will require identifying optimal implementation strategies and designing protocols that align with current evidence and can be used in real-world clinical settings.

Long-term outcomes: To date, only a few studies have examined real-world benefits for QoL or the impact on lifespan beyond 6–12 months, highlighting the need for long-term research.[47,74] It is important to understand how IoT interventions impact disease progression, treatment adherence, and overall patient survival. Long-term studies are needed to determine whether early improvements in symptoms and QoL translate into sustained clinical benefits over time.

Equity considerations: Digital literacy, access to technological tools, and socioeconomic circumstances can significantly influence the usability and acceptance of IoT-based interventions. For this reason, it is crucial to design implementation strategies that are relevant to people's real-life needs and contexts.[44,62] Certain groups, such as elderly patients or those with limited financial resources, may struggle with complex IoT platforms. Therefore, future applications should have a simple and user-friendly interface, provide appropriate training and technical support, and ensure cost-effective solutions so that all individuals can equitably benefit from these technologies.

Future research should focus on developing IoT platforms that are user-friendly, flexible, and integrated with AI. Moreover, their robust clinical validity across diverse cancer patient populations should be well-studied. By combining physiological monitoring, professional clinical assessment, and caregiver feedback, more comprehensive patient management can be achieved, ultimately improving long-term QoL.

Conclusion

The review demonstrates that IoT-based interventions have considerable potential to improve cancer patients' QoL. Wearable devices and integrated platforms have shown the greatest impact, as interconnected systems enhance patient engagement, enable real-time monitoring, and facilitate smoother communication with clinical teams—all of which contribute meaningfully to patient well-being. Breast cancer patients appear to benefit most from these methods, but evidence for other types of cancer is either limited or inconsistent.

The type of device also plays a significant role in adoption and effectiveness. Therefore, future digital health strategies should focus on user-friendly designs and proper system integration. Overall, the findings suggest that IoT technologies represent a promising avenue for improving QoL, improving symptom management, and achieving patient-centered outcomes in oncology care.

Authors' Contribution

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Project administration: Sima Saadi.
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Visualization: Sogand Habibi.
Writing–original draft: Sogand Habibi.
Writing–review & editing: Sima Saadi.

Competing Interests

The authors declare that they have no conflict of interests regarding the publication of this review.

Ethical Approval

None.

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