

Review

Design Requirements of Breast Cancer Symptom-Management Apps

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Abstract

Many breast cancer patients follow a self-managed treatment pathway, which may lead to gaps in the data available to healthcare professionals, such as information about patients' everyday symptoms at home. Mobile apps have the potential to bridge this information gap, leading to more effective treatments and interventions, as well as helping breast cancer patients monitor and manage their symptoms. In this paper, we elicit design requirements for breast cancer symptom-management mobile apps using a systematic review following the PRISMA framework. We then evaluate existing cancer symptom-management apps found on the Apple store according to the extent to which they meet these requirements. We find that, whilst some requirements are well supported (such as functionality to record multiple symptoms and provision of information), others are currently not being met, particularly interoperability, functionality related to responses from healthcare professionals, and personalisation. Much work is needed for cancer patients and healthcare professionals to experience the benefits of digital health innovation. The article demonstrates a formal requirements model, in which requirements are categorised as functional and non-functional, and presents a proposal for conceptual design for future mobile apps.



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1. Introduction

Over the past decade, pathways for breast cancer follow-up care in high-income settings have shifted decisively from scheduled hospital visits toward supported self-management models [1,2]. In the United Kingdom, for instance, approximately 70–75% of women with stage I–III breast cancer [3] are discharged from routine oncology clinics after primary treatment and instead monitor symptoms from home, accessing rapid response services only when red-flag symptoms arise [4–6]. This home-centred care pathway empowers patients and reduces outpatient congestion, yet it also creates an information gap: clinicians seldom obtain contemporaneous data on the side effects that emerge between visits, and patients may be uncertain whether selfcare is sufficient or clinical escalation is warranted [7].

A growing consensus suggests that MobileHealth (mHealth) applications could bridge this gap by capturing real-time patient reported outcomes (PROs) and delivering just-in-time self-management advice. Randomised and quasi-experimental trials of chemotherapy-specific apps, such as Interaktor [8], mPRO Mamma [9] and MSymptom [10], have already demonstrated significant reductions in symptom prevalence and symptom distress [11], alongside clinically meaningful gains in health-related quality of life (QoL). Nevertheless, the design requirements for breast cancer symptom management apps remain only partially conceptualized, and, to our knowledge, no published study has evaluated available apps against a formally derived requirement set. To address this evidence gap we pose two research questions:

RQ1: What are the design requirements for breast cancer symptom—management apps?

RQ2: How well do publicly available apps satisfy these requirements?

Our approach is two-pronged. First, we define the challenge from a systems perspective and perform a structured literature review from which we extract and formally model a comprehensive list of design requirements (Section 4). Second, we transform those requirements into an evaluation rubric and apply it to five leading breast cancer apps retrieved from the Apple App Store, thereby generating a quantitative profile of current practice (Section 5). Preliminary findings reveal pronounced strengths, such as multi-symptom logging and educational content, but also expose critical deficits in interoperability, real time clinician response mechanisms and personalisation. We argue that advances in artificial intelligence (AI) and machine learning (ML) could help close these gaps, yet the present state of the field remains limited in its capacity to support both patients and healthcare professionals [12].

The remainder of the paper is structured as follows. Section 2 reviews breast cancer symptomatology and the role of digital health in breast cancer care. Section 3 refines the scope of the problem by applying Soft Systems Methodology. Section 4 identifies and models app design requirements. Section 5 evaluates existing commercial apps against these requirements, and Section 6 presents a formal requirement model alongside a conceptual future app design. Section 7 discusses the implications of our findings, and Section 8 draws the principal conclusions. By integrating an updated empirical synthesis with a rigorous requirements engineering process, this paper provides an evidence-based blueprint for the next generation of breast cancer symptom management applications and highlights priority areas for innovation.

2. Background

2.1. Symptom Burden and Survivorship Needs

Breast cancer symptomatology is heterogeneous in both nature and severity because patients undergo markedly different treatment modalities, including surgery, radiotherapy, chemotherapy, endocrine therapy, and an expanding portfolio of targeted biologics, each of which vary in their side-effects and associated symptoms [13]. Chemotherapy, endocrine agents and HER2-targeted drugs can elicit fatigue, nausea, neuropathy, and cognitive changes, whereas surgery and radiotherapy often leave persistent pain, lymphoedema or restricted shoulder movement [14,15] as per National Comprehensive Cancer Network (NCCN) report [16]. In the United Kingdom, these complex trajectories are organised into stratified pathways that align follow-up intensity with clinical risk [5] (Figure 1). Early modelling suggested that approximately 70% of breast cancer survivors would be suited to a supported self-management route [5]; more recent evaluations placed the figure as high as 75% [6]. Real-world audits corroborate these estimates: Acreman et al. [17] reported that 83% of patients, more than half of whom had breast cancer, successfully self-managed breathlessness via a non-pharmacological pathway.

While self-management reduces unnecessary clinic visits, it also transfers responsibility for day-to-day symptom appraisal to patients and carers, heightening the risk that clinically significant toxicities will go unreported. Traditional paper-based patient reported outcome (PRO) diaries capture such events only intermittently. By contrast, electronic PRO (ePRO) systems and mobile applications can relay real-time symptom data to clinical teams, enabling timely interventions, enhancing patient-clinician dialogue [18] and, in some meta-static disease trials, improving overall survival [19,20]. mHealth proved useful for early breast-cancer symptom reporting and management [21]. Evidence specific to breast cancer is rapidly accumulating. In the first mobile-intervention randomised controlled trial (RCT) in this field, Egbring et al. [22] demonstrated that a diary-based app stabilised patients' Eastern Co-operative Oncology Group performance status and detected >50% more grade ≥ 2 toxicities than paper forms. Subsequent trials added critical design insights: a web-linked platform with threshold email alerts halved clinician response time and reduced high-grade nausea and fatigue [23]; an interactive app that combined daily symptom entry with nurse-triggered SMS advice cut symptom distress scores during neoadjuvant chemotherapy [8]; a gamified education tool improved oral-therapy adherence and lowered neuropathy prevalence [24]; and an SMS-feedback app (M-Symptom) significantly reduced the MSAS physical-symptom sub-scale [10]. Observational and cohort studies echo these findings, reporting higher global QoL [24] and strong user acceptance across diverse demographics [25,26].

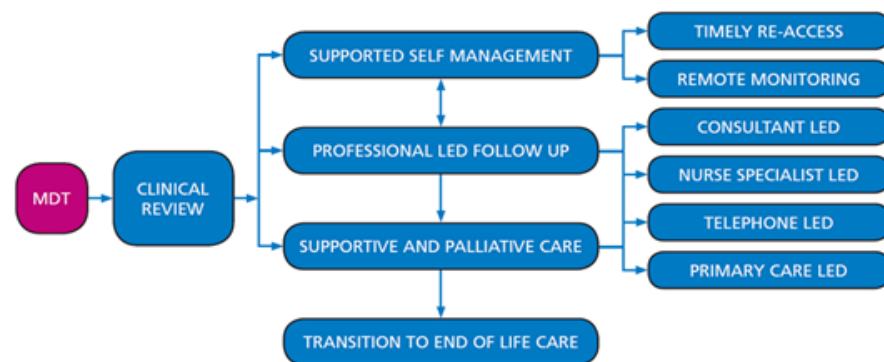


Figure 1. Stratified follow-up pathway model by Northern Cancer Alliance [27]. NB: MDT stands for 'multidisciplinary team'; LED stands for 'locally employed doctors'.

2.2. Digital Readiness and Equity Considerations

Digital health refers to the use of information and communication technology tools to monitor health, deliver treatment, and enhance professional decision making [28]. Mobile health (mHealth) is a subset of digital health and is formally defined by the World Health Organization's Global Observatory for eHealth as "medical practices supported by mobile devices" [29,30]. mHealth systems leverage smartphones, tablets, digital assistants and interconnected sensors to collect real-time patient data, visualise physiological trends and connect the wider care team, thereby liberating diagnosis and follow-up from geographical constraints [31–34].

Adoption rates among breast cancer survivors are encouraging. In a survey of 210 patients, 69% reported using a mobile phone every day and more than half used smartphone functions to manage appointments and recovery tasks [35]. Commercial figures mirror this: smartphone penetration in high-income jurisdictions now exceeds 70%. Yet these averages mask a digital access gap: older adults, rural residents and women with limited e-health literacy remain less likely to own internet-enabled devices or feel confident navigating apps. Effective interventions must therefore pair intuitive interfaces with explicit accessibility

features, adjustable fonts, audio prompts, and multilingual content, and include outreach strategies to minimise exclusion [36,37].

Although the Apple and Google marketplaces list over 165,000 medical or health related apps, most lack any form of scientific validation. In one review of 279 pain related apps, just a single product had undergone formal evaluation [38]. This evidence vacuum reinforces the imperative to articulate robust design requirements for breast cancer symptom-management apps and to evaluate existing offerings against those criteria to ensure that digital tools fulfil their clinical promise [39,40].

2.3. State of the Evidence

While these trials collectively support mHealth's feasibility and highlight the clinical value of features such as real-time clinician alerts, they also reveal critical shortcomings: none of the evaluated products interfaced directly with electronic health record (EHR) systems, only two protocols referenced plans to incorporate AI-driven personalisation [41], and no study benchmarked its intervention against a formally derived set of user or system requirements. In addition, although smartphone adoption among breast cancer survivors is now high (71% reported access in a 2012–2020 UK longitudinal cohort [42] and 69% reported daily mobile-phone use in an earlier survey [35]), approximately one-fifth of patients still lack smart devices, underscoring a persistent digital divide linked to age and socioeconomic status. The current situation thus has three systemic deficits that persist. *Digital-access inequity* remains; roughly one-fifth of breast cancer survivors, particularly older or rural women, lack smartphones or confidence in mHealth tools [42]. *Interoperability* is poor; none of the published apps push structured data into oncology EHRs [9,43]. Finally, *personalisation* and two-way communication remain rudimentary: only a minority of interventions offer AI-based tailoring or real-time clinician chat [38].

To realise the full potential of mHealth within supported self-management pathways, future research must (a) establish consensus design requirements that capture patient and clinician needs, (b) evaluate existing apps against those criteria to map capability gaps and (c) address structural barriers, notably interoperability and equitable access, that currently limit scalability beyond pilot settings.

3. Problem Definition

A Soft Systems Methodology (SSM) [44] exercise consistent with the longstanding use of a systems lens in Information Systems and Digital-Health research [45] was employed to structure this multistakeholder, ill-defined problem space. The resulting rich picture is a conceptual model enabling learning about ill-defined problems. Figure 2 maps interactions among patients, oncologists, ward nurses, community, family caregivers, appointment systems and regulatory bodies; concise element definitions appear in Table 1. Under conventional pathways, a typical cancer patient must attend hospital frequently for diagnostic imaging, systemic therapy, toxicity monitoring, prescription collection and follow-up. Family members and other support network actors remain largely disconnected from these information flows and therefore receive only generic advice that is seldom tailored to each patient's evolving needs. Conversely, service providers must simultaneously meet caregiver expectations and comply with stringent regulatory requirements for data security and clinical governance.

Analysis of the rich picture surfaced three inter-related system-level deficits that blunt the effectiveness of current supported self management pathways. First, data discontinuity: once patients leave the infusion suite, clinicians have no structured mechanism for capturing day-to-day symptom trajectories. Second, an equity divide: older adults and digitally disadvantaged patients are far less likely to engage with existing symptom-tracking tools.

Third, an interoperability deficit: most commercial apps function as sealed ecosystems that cannot exchange structured data with hospital information systems, forcing clinicians either to log into separate dashboards or to ignore app data altogether.

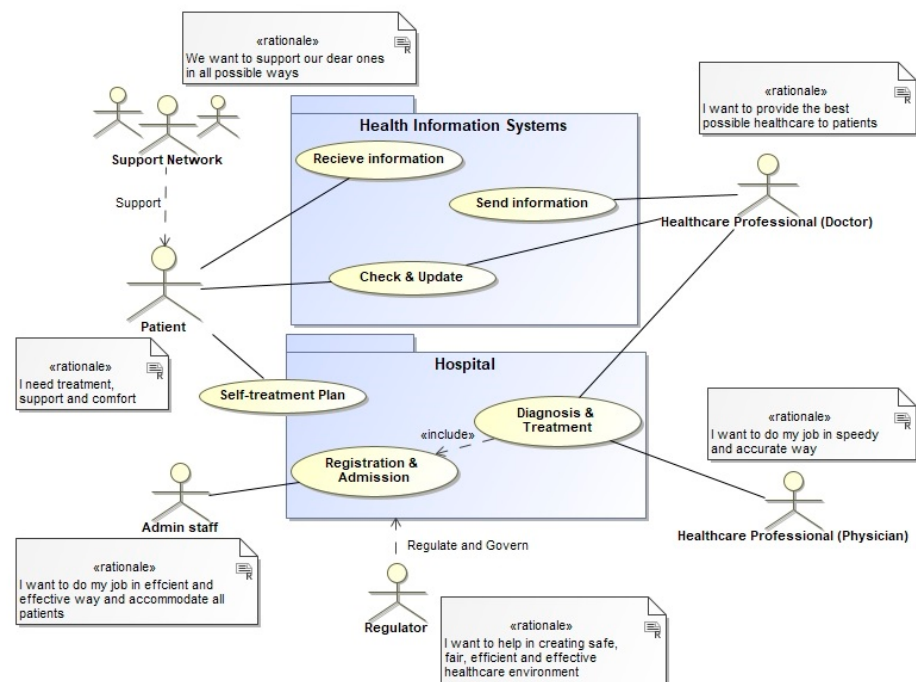


Figure 2. Breast cancer treatment (rich picture).

Table 1. Rich picture CATWOE details.

CUSTOMER	PATIENTS AND THEIR FAMILIES
ACTOR	Breast cancer multi-disciplinary treatment team: doctors, physicians, regulator, app owner, app administrator
TRANSFORMATION PROCESS	Provide information, diagnostic investigations, treatments, managing symptoms, emotional support
WORLDVIEW	A belief that multidisciplinary and patient self-managing app enables better diagnosis, treatment, care management and support that lead to improved patient outcomes and cost reduction
OWNER	NHS or third-party health services provider
ENVIRONMENT	Knowledge base, clinical guidelines, physical and technological constraints, patient health records, patient target times
PERFORMANCE MEASURES	Effectiveness: goal-orientated, data completeness, data accuracy, usability. Efficiency: Cost-saving, timesaving, error-free, availability

Any viable digital solution must therefore pursue three objectives simultaneously. It must (1) solicit multidimensional symptom input with minimal user burden; (2) deliver actionable, personalised feedback to both patients and clinicians, ideally alerting healthcare professionals when symptom patterns become concerning; and (3) transmit data securely to the EHR and broader care network to ensure continuity of care and compliance with governance frameworks.

4. Requirements Identification

4.1. Literature Search Process and Systematic Review

After defining the problem scope, we conducted a systematic literature review to elicit documented requirements and best practices for mobile app-based symptom management in breast cancer. The review followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Four databases (PubMed, Scopus, CINAHL, PsycINFO) were searched up to 15 January 2025, using keywords such as “breast cancer”, “symptom management”, and “mobile application”. We also piloted broader terms (e.g., “oncology app”, “symptom tracker”) but these did not yield additional eligible records. After removing duplicates, the titles and abstracts of 67 unique results were screened against predefined exclusion criteria (non-breast cancer population, no intervention or evaluation, not a mobile app focus, no symptom management content, or non-English). This screening excluded irrelevant or ineligible papers, leaving 41 articles for full-text assessment. Further application of inclusion criteria (requiring studies to report on a breast cancer symptom-management app intervention or evaluation) led to a final set of over a dozen pertinent studies published between 2016 and 2024 for in-depth analysis. Figure 3 illustrates the PRISMA flow of study selection [46,47].

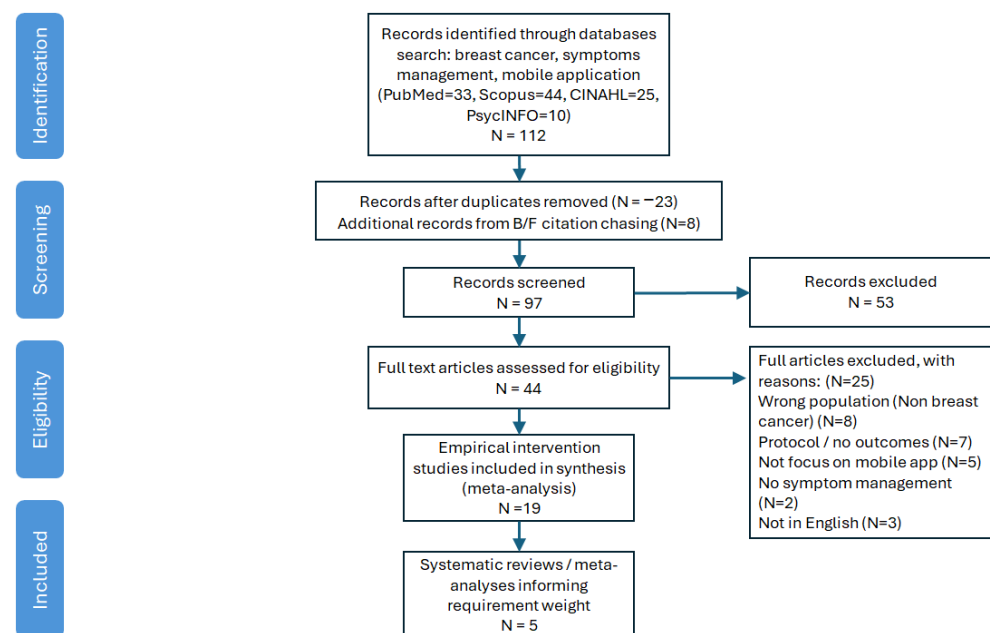


Figure 3. Flow diagram of screening process of applying mobile applications in symptom management of breast cancer patients using PRISMA [47].

Following the approach recommended by Jongerius et al. [48], two reviewers independently extracted each study’s objectives, design, sample, intervention features, and outcomes, reaching consensus on any discrepancies. The included studies spanned randomized controlled trials (RCTs), quasi-experimental and feasibility studies, mixed-methods evaluations, and qualitative analyses across Asia, Europe, and North America. In total, these works enrolled hundreds of breast cancer patients (typically 40–150 per study) using at least five distinct symptom-management apps. Notably, our review also incorporated several recent systematic reviews and meta-analyses that have synthesized broader evidence on cancer symptom-management apps [48]. This comprehensive literature base provides a robust foundation for identifying which app features and design elements consistently support effective symptom management.

4.2. Literature-Derived Requirements

The final review set comprised twelve empirical studies published between 2016 and 2021 (Table 2, ordered chronologically). Designs covered randomised controlled trials (e.g., [8,22,23,49]), mixed-methods feasibility studies [50,51] and secondary log analyses [52]. Sample sizes ranged from 42 to 149 patients, with intervention periods from 3 weeks to 6 months. All interventions incorporated at least one symptom-related feature, daily PRO diaries, threshold-based alerts, or self-care tip modules, and each study reported at least one positive outcome attributable to the app:

- Symptom relief and distress reduction [8,11,49].
- Stabilisation of functional status when clinician review was integrated [22].
- Earlier clinical response through real-time alerts [23].
- Higher self-efficacy and short-term QoL gains from education-plus-forum designs [24,53].
- Improved medication adherence via gamified or dashboard-driven reminders [23,24].
- High user engagement and perceived connectedness to care teams [50,51].

Table 2. Literature review Summary.

#	Study (Year, Country)	Design & Sample	App/Platform	Mobile Design Highlights	Primary Outcome Category
1	Egbring et al. [22] (CH)	3-arm RCT, N = 139 adjuvant chemo	(custom)	Daily CTCAE diary; physician-review arm	Functional status stabilised; more grade ≥ 2 toxicities detected
2	Graetz et al. [23] (US)	Multi-centre RCT, N = 120	SymptomCare@Home	PRO-CTCAE diary $\rightarrow$ EHR alerts; colour dashboard	Faster nurse response, $\downarrow$ grade ≥ 2 nausea/fatigue
3	Kim et al. [24] (KR)	RCT, N = 76 metastatic	Chemo-Game	Gamified education, quizzes, med log	$\uparrow$ adherence; $\downarrow$ nausea, neuropathy
4	Zhu et al. [53] (CN)	Multi-centre RCT, N = 114	Breast-Cancer e-Support	“Learn–Discuss–Ask” forums; nurse moderation	$\uparrow$ self-efficacy, $\downarrow$ symptom interference
5	Handa et al. [54] (JP)	RCT, N = 102	BPSS	Cycle-based logging; shared record	1868 AEs surfaced; no QoL change
6	Fjell et al. [8] (SE)	RCT, N = 149 neo-adjuvant	Interaktor	Real-time nurse SMS alerts; self-care library	$\downarrow$ nausea, distress; $\uparrow$ emotional QoL
7	Kuhar et al. [9] (SI)	Prospective cohort, N = 91	mPRO Mamma	50-symptom diary; tailored tips; reminders	$\uparrow$ global QoL week 1; $\downarrow$ pain
8	Cheng et al. [55] (HK/AU)	RCT protocol	B-CApp	Self-management CBT modules; nurse chat	(Protocol)
9	Lidington et al. [56] (UK)	RCT protocol	OWise	NHS-linked clinician portal; FHIR export	(Protocol)
10	Cinar et al. [49] (TR)	Parallel-group RCT, N = 80	e-Symptom Tracker	Twice-daily diary; push tips	$\downarrow$ MSAS distress; $\uparrow$ QoL
11	Aydın & Gürsoy [57] (Global audit)	App-store survey	–	MARS quality & functionality scoring	37% apps lacked evidence-base
12	Sohrabei & Atashi [58] (IR)	Systematic review	–	–	mHealth $\downarrow$ distress, $\uparrow$ empowerment
13	Ahmadi et al. [59] (IR)	Development + usability, N = 40	BCRL Self-Care	Lymph-exercise videos; AI reminders	System Usability = 84/100
14	Tian et al. [60] (CN)	Network meta-analysis	–	VR modules (pain, anxiety)	VR $\downarrow$ pain & fatigue vs. control
15	An et al. [61] (KR)	Systematic review (15 trials)	–	–	Highlighted need for mental-health & clinician feedback

Table 2. Cont.

#	Study (Year, Country)	Design & Sample	App/Platform	Mobile Design Highlights	Primary Outcome Category
16	BorjAlilu et al. [62] (IR)	Rapid review	–	–	Emphasised AI for mental-health support
17	Jiang et al. [63] (CN)	RCT, N = 102 young survivors	AI-TA	Intelligent follow-up; mood check-ins	↓ distress & fatigue; ↑ self-efficacy
18	Mollaoğlu et al. [64] (TR)	X-sectional app-use study	–	Post-surgery symptom diary	Linked app use ↔ better function
19	Park et al. [65] (KR)	Quasi-exp., N = 88 survivors	mHealth-Coach	Behaviour-change AI; video chat	↓ symptom cluster; ↑ QoL & self-management

Abbreviations: AE = adverse event; CTCAE = Common Terminology Criteria for Adverse Events; EHR = electronic health record; MSAS = Memorial Symptom Assessment Scale; PRO = patient-reported outcome; QoL = quality of life; RCT = randomised controlled trial; CBT = cognitive behavioural therapy; AI = artificial intelligence; VR = virtual reality; BCRL = breast-cancer-related lymphoedema.

The body of literature reviewed consistently shows that well-designed mobile apps can improve patient outcomes during breast cancer treatment by facilitating symptom self-management. The included app interventions addressed a range of functionalities, from daily symptom tracking and education to clinician communication, and collectively demonstrated multiple benefits. For example, several RCTs reported *reduced symptom burden and distress* in the intervention groups using symptom-management apps [58]. Fjell et al. [8] observed significant decreases in chemo-related symptoms (e.g., nausea, fatigue) and overall distress when nurses received real-time alerts from a patient app. Cinar et al. [49] similarly found that high-frequency symptom diary use plus push self-care tips led to lower symptom distress and improved quality of life. Other trials noted *improvements in functional status*; Egbring et al. [22] showed that an app with physician-linked feedback helped stabilize daily functioning during chemotherapy. Apps with alert features have also enabled *earlier clinical interventions* [66]; Graetz et al. [23] reported that automated symptom alerts to providers facilitated quicker responsive care. Beyond physical symptoms, apps are helping address psychosocial health. Jiang et al. [63] demonstrated that an “intelligent” app with biweekly two-way follow-up significantly reduced young patients’ psychological distress and fatigue while boosting self-efficacy. This reinforces the findings by Sohrabei and Atashi [58], who noted that mobile health interventions can lessen patients’ symptom-related distress and improve feelings of social support and empowerment. In sum, the literature indicates that symptom-management apps, when thoughtfully implemented, can enhance quality of life, promote timely care, and increase patients’ confidence in managing their condition [48,63].

From the review, we extracted a set of core requirements for an effective breast cancer symptom-management app, mapping each to the evidence base. These requirements and exemplary supporting studies are summarized below:

Symptom Tracking (Diary): The app must support easy, frequent logging of symptoms (and side effects) with severity ratings. Nearly all studies included a symptom diary as a central feature. For instance, Kuhar et al. [9] describe an app (“mPRO Mamma”) enabling *daily tracking of up to 50 symptoms with severity levels*, which in turn triggers tailored self-care advice [9]. Regular logging—ideally daily or even twice-daily during treatment—is critical for accurate monitoring. To maximize adherence, data entry should be streamlined (e.g., preset lists and sliders) such that patients can record a symptom in just a few taps. High compliance rates (often $\geq 75\%$) were achieved in trials where *logging was made simple and quick*, underscoring the importance of usability in diary design [67,68].

Alerts and Triage: An effective app provides threshold-based alerts that notify either patients or clinicians (or both) when reported symptoms reach concerning levels [68].

Several interventions incorporated automated alert systems, for example, the Interaktor app would send nurses an SMS alert if a patient's symptom score was above a preset threshold. Such alerts have been linked to earlier medical responses and better symptom control. Some apps also send the patient push notifications as *reminders or advice* when concerning symptoms are logged (e.g., "You reported severe pain; consider taking your rescue medication and inform your doctor") [69]). *Triage algorithms* can be built in so that high-grade symptoms prompt the recommendation to seek care. Graetz et al. [23] found that an EHR-integrated alert system led to significantly faster clinical actions, potentially preventing complications. In short, *real-time alerting* and triage logic ensure that severe symptoms are not overlooked, making the app an active safety net.

Patient Education & Self-Care Resources: Virtually all successful apps include an educational *library of self-management tips* and informational content [70,71], often context-sensitive. Kapoor et al. [72] reviewed survivorship apps and found *educational content to be the most common feature*, present in the majority of apps. This can take the form of articles, FAQs, or short videos covering topics like managing nausea, exercises for lymphoedema, nutrition during chemo, etc. Critically, several apps trigger specific advice based on the patient's current symptoms. For example, the mPRO Mamma app provides in-depth recommendations immediately after a user logs a symptom, tailored to the severity reported (e.g., steps for managing mild vs. severe nausea) [9]. Handa et al. [54] and Kuhar et al. [9] both emphasize that *just-in-time guidance* within an app can improve patients' self-care and confidence. A scoping review by Putranto and Rochmawati [69] further noted that effective symptom apps deliver information through *varied media*, not only text, but also videos, illustrative avatars, and culturally tailored content, to cater to different learning needs. Thus, a requirement is for comprehensive, *multimedia educational resources* in the app, ideally personalized to the user's situation [73].

Data Visualization and Feedback: Transforming logged data into intuitive visual feedback is important for patient insight. Several studies highlight the value of trend graphs and summaries. In Crafoord et al. [50], patients rated the ability to see symptom trends over time as a highly useful feature that helped them feel more in control. Apps should therefore include dashboards or charts that show, for example, pain levels over the past weeks, or fatigue patterns across chemotherapy cycles [74,75]. This aligns with the requirement of *data presentation*: giving patients feedback on their progress and symptom trajectory. Such visualization not only improves self-awareness but can also be shared with clinicians during visits. Some apps even compare patient scores to normative values (e.g., average cohort scores) to help patients contextualize their experience; a feature suggested in forward-looking requirements. Overall, *patient-facing data visualization* (charts, color-coded symptom severity indicators, etc.) is a recommended design element to enhance self-monitoring.

Communication and Social Support: The app should facilitate communication channels, both with healthcare providers and, where possible, with peers or caregivers. Many breast cancer patients feel reassured by knowing they can easily contact their care team when needed [76]. Accordingly, *in-app messaging or a "virtual coach/nurse" contact* is a common requirement. For example, Kelleher et al. [51] reported that patients explicitly requested a built-in chat with clinicians after using a symptom app without one. Cheng et al. [55] found that an app offering *proactive nurse support*, where nurses could review symptoms remotely and follow up, was met with very positive patient and provider feedback. Indeed, incorporating two-way communication improves patients' trust that their symptoms will be addressed in a timely fashion. In addition to patient-provider communication, some apps provide *peer support communities or social networking* features. Kapoor et al. [72] noted that social support forums were the second most common feature

in survivor apps (after education). While not all clinical apps include peer interaction, evidence suggests that moderated forums or the ability to share experiences can reduce isolation and anxiety. Houghton et al. [76] identified *social support* as a key theme for mobile health in breast cancer care, with apps being used to connect patients with fellow survivors for encouragement. Therefore, an ideal symptom-management app should include *secure messaging*, enabling patients to ask questions or share data with clinicians, and potentially community features or caregiver sharing options to bolster support.

Psychological Well-Being and Mental Health Support: Beyond physical symptom tracking, the design should address mental and emotional health. Several interventions included mood or anxiety assessments and relevant resources (e.g., relaxation exercises, mindfulness coaching). Evidence is growing that such features have tangible benefits. For example, *depression and anxiety scores* were often secondary outcomes in app trials. Seven et al. [77] observed that women using a symptom app had significantly *lower increases in depression/sadness* over chemotherapy than controls, implying mood-tracking and supportive content in the app helped mitigate psychosocial decline. Park et al. [34] similarly underscore the value of integrating *mindfulness or cognitive-behavioural strategies* into apps to improve patients' emotional well-being (e.g., guided breathing exercises or CBT-informed coping tips embedded in the app). In Jiang et al. [63], the AI-TA app's "intelligent design" explicitly targeted psychological health and led to reduced distress and fear of recurrence in young survivors. Thus, a requirement is that apps provide features for *mental health support*; this could include mood diaries, stress management tutorials, or simply content on coping with cancer's emotional impact. Such features contribute to overall symptom management since psychological distress can exacerbate physical symptoms [58].

Personalization and AI-Driven Insights: An emerging requirement is the ability to tailor content and recommendations to the individual. Patients vary in age, culture, health literacy, and symptom profiles; apps that adapt to these differences can enhance engagement. Traditional personalization includes allowing users to set preferences (e.g., topics of interest, notification frequency) and the app adjusting educational content accordingly. For instance, older patients might prefer larger text and simpler interfaces, whereas younger patients may use more advanced features, Zhu et al. [43] observed usage patterns differed by age and education, suggesting content and UI should adapt to user demographics. Beyond user-driven customization, *AI offers dynamic personalization*. Modern apps are beginning to incorporate AI algorithms that analyze a patient's logged data to provide tailored feedback or even predictions. BorjAlilu et al. [62] conducted a review of AI-based tools for chemotherapy toxicity prediction in breast cancer, underlining the potential for apps to include predictive analytics that warn of high-risk symptoms or complications. While still nascent, one can envision an app detecting that a patient's pattern of escalating neuropathy and fatigue is concerning and proactively advising a dose review or clinic visit (an AI-driven "insight"). Some current apps already include rudimentary decision support, for example, symptom triage logic or content prioritization based on user data. The AI-TA app studied by Jiang et al. [63] exemplifies this trend: it used intelligent algorithms to personalize follow-up and content, which contributed to better outcomes. We therefore identify *AI-driven insight/personalization* as a forward-looking functional requirement: the app should learn from the individual's inputs over time to refine the support it provides [63]. This could range from simple rules (e.g., highlighting education on sleep if the user logs insomnia) to complex machine learning predictions of symptom trajectories.

Integration with Clinical Systems (Interoperability): For maximal impact, symptom apps should not exist in a silo but rather integrate with the broader healthcare system. Clinicians need efficient access to patient-reported data. Many reviewed studies emphasized

this integration. For example, some apps generated summary reports or PDFs that patients could share with providers (as noted in MyBreastCare's evaluation). More advanced interoperability involves linking the app to electronic health records (EHRs). Graetz et al. [23] and Warner et al. [78] both connected their apps to EHR platforms so that alerts and data flowed directly to oncology clinics. In practice, an app meeting this requirement might allow *secure data export or API integration* with systems like Epic or Cerner. The OWise breast cancer app, for instance, has the capability to feed patient-entered symptom and quality-of-life data into the hospital's EHR in real time [75]. This enables the care team to monitor the patient between visits and incorporate app data into clinical decisions [75]. Interoperability also extends to involving multiple stakeholders: caregivers or nurses could access patient data through linked accounts or web portals with permission. Overall, *connectivity* with clinical IT systems and care teams is a key requirement, ensuring the app complements and informs professional care rather than functioning in isolation.

Usability and Accessibility: Even the most feature-rich app will fail to achieve adoption without a strong emphasis on usability. Breast cancer patients include older adults and those dealing with treatment side effects that can impair concentration or dexterity, so *simple and intuitive design* is paramount. Common usability requirements include a clean interface with large, easy-to-press buttons, minimal steps to log information, and support for multiple languages or low-literacy modes [67]. Several trials achieved high adherence by focusing on usability, Cinar et al. [49] reported over 75% adherence when diary entry was designed to take less than two steps. In Ahmadi et al. [59], a mobile app for managing breast cancer-related lymphedema was found *highly usable* (scoring well on the QUIS usability scale) because it was developed through user-centered design and needs assessment. The app's functions (symptom logging, medication reminders, exercise tracking, etc.) were organized in a patient-friendly way, and this led to patient satisfaction and engagement [59]. We also must consider accessibility features like offline access (caching data when internet is unavailable) and compatibility with assistive technologies can be crucial for some users. Ultimately, the app should be *easy to learn, navigate, and incorporate into daily life*, imposing minimal burden. High usability not only improves uptake but is directly tied to better outcomes; if recording a symptom is too cumbersome, patients simply won't do it, defeating the purpose.

Privacy and Security: Lastly, any application dealing with personal health data must ensure robust privacy and security protections. While this was not the primary focus of the intervention studies, virtually all papers acknowledged this as a baseline requirement. Breast cancer patients expect their data (symptom reports, journal entries, etc.) to be kept confidential and transmitted securely. In practical terms, this means compliance with regulations (such as HIPAA in the US or GDPR in Europe), e.g., using encryption for data storage and transfers, secure user authentication, and transparent data use policies. Several reviewed apps explicitly mentioned using secure cloud infrastructure and multi-factor login to protect patient information. Although specific security measures were often not detailed in publications, we include *data privacy/security* as a non-functional requirement that underpins user trust. An example is the design by Lidington et al. [56] of the OWise platform within the NHS: it underwent rigorous security evaluation before being included in the NHS Apps Library [75]. Users are more likely to engage with an app if they trust that their sensitive data (e.g., symptom severity or mood reports) will not be misused or exposed [79].

Our analysis led to identification of literature-driven requirements that cover core capabilities, symptom capture, alerting, tailored education, visualization, communication, etc. and important attributes, such as interoperability, usability, personalization, and

privacy. Table 3 organize these into Functional Requirements (FR) and Non-Functional requirements (NFR) and shows the weights and evidence density.

Table 3. Elicitation and weighting App Requirements.

ID	Requirement	Weight	Studies Supporting (<i>n</i>)	Representative Refs
FR1	Multi-symptom diary with severity scale	3	15	Egbring [22]; Kuhar [9]; Jiang [64]
FR2	Threshold-based patient & clinician alerts/triage	3	9	Graetz [23]; Fjell [8]; Park [34]
FR3	Context-specific self-care library (text, video)	3	14	Kuhar [9]; Ahmadi [59]
FR4	Two-way messaging/clinician portal	2	8	Cheng [55]; Lidington [56]
FR5	Symptom-trend visualisation dashboards	2	7	Crafoord [50]; OWise
FR6	VR-based symptom distraction	1	3	Tian [60]
FR7	Mental-health modules (mood diary, CBT, mindfulness)	2	6	Jiang [63]; Park [34]; BorjAlilu [62]
FR8	AI-driven coaching/prediction	1	4	Ahmadi [59]; Park [34]
NFR1	Usability & accessibility (≤ 2 taps per entry, large UI, multi-language)	3	14	Cinar [49]; Aydin [57]
NFR2	Privacy & security (GDPR/HIPAA, encryption)	3	11	Lidington [56]; Sohrabei [58]
NFR3	Interoperability (HL7 FHIR, PDF export, wearables)	2	8	Graetz [23]; OWise
NFR4	Reliability & data backup	2	5	Egbring [22]; Handa [54]
NFR5	Regulatory sustainability (DTAC, FDA SaMD)	1	4	Lidington [56]; An [61]

Weights applied in Section 5 are: FR1–3, NFR1–2 = 3 (critical); FR4–5, NFR3–4 = 2; FR6–8, NFR5 = 1–2 according to evidence maturity (Table 3).

Notably, these features are deeply interrelated: for instance, effective symptom tracking (FR1) is tied to simplicity of use (NFR1: usability), and communication features (FR4) rely on proper interoperability and security (NFR3 and NFR2) [6,75]. The review also highlights growing interest in *AI-enhanced and personalized functionalities* that go beyond what current apps typically offer. The scoring followed a three-step:

1. **Evidence tagging:** every feature reported in ≥ 2 empirical trials or highlighted in ≥ 1 systematic review was tagged with its primary patient-need (capture, respond, empower) and evidence strength (number of supporting studies).
2. **Requirement clustering:** tagged features were clustered into functional requirements (FR) and non-functional requirements (NFR) using standard ISO/IEC 25010 categories.
3. **Criticality weighting:** each requirement was assigned a weight (1 = nice-to-have, 3 = critical) proportional to (i) the volume of evidence and (ii) the magnitude of outcome benefit reported.

In the next sections, we will assess how well existing commercial apps meet these requirements (Section 5) and propose a conceptual design that implements them (Section 6).

5. Screening, Evaluation and Benchmarking Leading Mobile Apps

5.1. Marketplace Screening

We conducted our structured marketplace scan to determine how well commercial products meet the expanded requirement set in Table 3. Using the keyword “breast cancer” in the Apple App Store returned 165 hits. After applying technical filters (iOS version ≥ 15 , updated within the past 12 months, English interface, free-to-download) and clinical-content filters (explicit focus on breast cancer and at least one symptom-management feature), five apps met all inclusion criteria:

1. OWise Breast Cancer
2. Outcomes4Me Cancer Care

3. Wave Health/chemoWave (same developer ecosystem)
4. Breast Cancer Manager
5. CancerAid

These products all have $\geq 10,000$ downloads and active developer support; four are also available on Google Play. Feature verification drew on the public app descriptions, developer white papers and in-app testing sessions conducted by two reviewers.

5.2. Scoring Framework

The shortlisted apps were evaluated with a weighted scoring rubric from 0-to-5 which reflect the eight functional requirements (FR1–FR8) and five non-functional requirements (NFR1–NFR5) identified in Section 4.2. Each requirement is weighted (1–3) according to criticality and evidence density (Table 3). The maximum attainable score is 140 points (functional = 85; non-functional = 55). Scoring rules were refined as follows:

- Mental-health support (FR7)—an app scored 5 only if it offered a validated mood diary plus guided CBT/mindfulness modules; mood tracking alone warranted ≤ 3 .
- AI-driven coaching (FR8)—a 5 required machine-learning-based insight or prediction (e.g., adaptive treatment guidance); simple rule-based tips scored ≤ 3 .
- VR distraction (FR6)—because no breast-cancer-specific VR apps are in the stores, all evaluated products scored 0 here, highlighting an innovation gap.

Three reviewers applied the rubric independently; discrepancies were $\leq 5\%$ of total points and resolved by consensus. Table 4 depicts the weighted requirement performance for each app.

Key observations

- **Interoperability** remains the decisive differentiator: OWise is the only product with live HL7 FHIR feeds into hospital EHRs.
- **Mental-health features (FR7)** are still embryonic. Only Wave Health and Outcomes4Me offer mood tracking; none deliver structured CBT or mindfulness curricula.
- **AI personalisation (FR8)** is emerging: Outcomes4Me uses AI to translate NCCN guidelines into lay recommendations, while Wave Health correlates self-reported behaviours with symptom trends. Both score ≥ 3 , but neither performs predictive toxicity forecasting as described in BorjAlilu et al. [62].
- **VR symptom distraction (FR6)** is entirely absent in the consumer marketplace, reinforcing Tian et al.'s [60] call for VR integration.

Table 4. Apps evaluation against the identified requirements.

App	Total/140	Strengths	Key Shortfalls
OWise	103	Best-in-class symptom diary; clinician portal with HL7 FHIR export, real-time dashboards (OWise US); rich education library; high usability; GDPR audit passed.	No VR (FR6); AI analytics limited to trend plots (FR8 = 2); mental-health content basic (FR7 = 2).
Outcomes4Me	92	AI-driven guideline translation and treatment matcher (Apple); colour-coded symptom graphs (Outcomes4Me); genetics/clinical-trial finder; community forum.	No clinician alert loop (FR2 = 1); data export only via PDF (NFR3 = 2); mental-health tools limited to curated articles (FR7 = 2).
Wave Health/chemoWave	72	Multimodal diary (symptoms, mood, activity); correlation engine uses AI to link behaviours and symptom severity (Google Play); medication reminders; user-defined goals.	No direct clinician connectivity; education library shallow; lacks VR, advanced mental-health programmes and formal security disclosures.

Table 4. *Cont.*

App	Total/140	Strengths	Key Shortfalls
Breast Cancer Manager	55	Daily journal with slider input and trend charts; medication scheduler; photo upload for visible symptoms; optional provider-view account (Apple).	Alert logic rudimentary; no AI or mental-health modules; interoperability relies on manual data sharing; interface dated (usability = 3).
CancerAid	34	“Champions” feature lets users share data with family/friends for support (Medibank); library of survivor stories; basic symptom log.	Missing clinician portal, alerts, mental-health content, AI insights; low diary flexibility; no EHR integration; lowest overall security transparency.

FHIR = Fast Healthcare Interoperability Resources.

All five apps meet basic privacy criteria (NFR2) and obtain ≥ 4 for usability (NFR1), reflecting the sector’s maturity in front-end design.

5.3. Gap Analysis and Implications for Design

The updated benchmarking confirms that core logging and education are now commoditised, but next-generation requirements, real-time clinician feedback, AI-based coaching, mental-health support and VR, remain unmet or only partially met. Table 4 shows that aggregate scores across apps plateau at ~70–85% of the maximum, with the steepest deficits in FR6–FR8 and NFR3. These gaps echo the literature synthesis:

- Clinical trials demonstrate that nurse-triggered alerts lower symptom burden [8,23], yet only one app implements a robust alert workflow.
- Psychological distress is a major unmet survivorship need; Jiang [63] and Park [65] show that intelligent, app-based mental-health modules reduce anxiety and fatigue, but such modules are largely absent from commercial offerings.
- No mainstream app exploits VR, despite mounting evidence of its efficacy for pain and fatigue [60].
- AI functionality remains descriptive rather than predictive; future apps should incorporate validated toxicity-prediction models as reviewed by BorjAlilu [62].

Consequently, the conceptual design in Section 6 prioritises:

1. Bidirectional FHIR-based integration to close the alert loop with oncology teams.
2. Modular mental-health tools (mood diary, CBT, mindfulness) with evidence-based content libraries.
3. Pluggable AI engine for personalised coaching and early-warning analytics, leveraging accumulated symptom trajectories.
4. Optional VR module for patients who can access a headset, fulfilling FR6.

By targeting these deficits, future mobile platforms can move beyond passive logging to deliver proactive, holistic, and integrated symptom management for breast-cancer survivors.

6. Requirements for Future Design of Breast Cancer Symptom-Management Apps

6.1. Requirements Modelling

The previous section identified the gaps in the current breast cancer symptom-management apps. We mapped the evidence synthesised in Section 4 to a formal goal-oriented requirements model (Figure 4) where purple signifies NFRs and pink FRs.

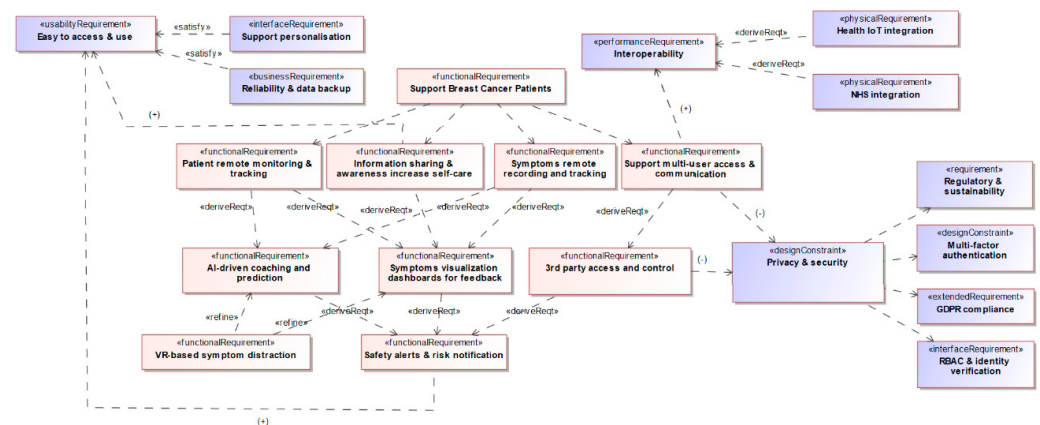


Figure 4. Requirements hierarchy and interdependency model.

The resulting hierarchy comprises eight FRs and five top-level NFRs. Figure 4 illustrates these relationships, the three top-level service goals Capture (FR1 + FR5), Respond (FR2 + FR4), Empower (FR3, FR6–8) sit above the eight FR nodes; arrows show how each FR supports (+) or harms (−) NFR satisfaction. This hierarchy provides a blueprint for the *next generation* of breast-cancer symptom-management apps, flagging where the commercial market (Section 5) still lags behind the evidence-based design envelope.

6.2. Conceptual Design of Breast Cancer Symptom-Management Apps

By integrating the identified requirements, future breast cancer symptom-management apps can better empower patients in self-care while facilitating timely medical support. We propose a high-level conceptual design for a breast cancer symptom-management system (Figure 5). This design is intended to illustrate how an app could be structured to meet the requirements and fill the gaps identified in existing solutions. At a high level, the system consists of four inter-locking artefact classes, social, knowledge, status/geo-location, and technical, and explicitly links them to the needs of patients, informal carers, clinicians, pharmacists, insurers, and regulators.

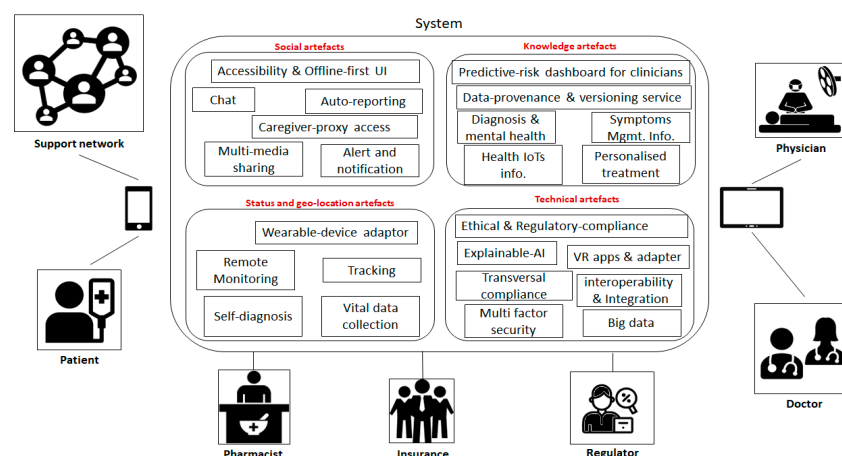


Figure 5. Future design of breast cancer self-management app.

Each class is summarised below, with emphasis on how the requirements are addressed through the functionality and strengthen regulatory, clinical, and equity credentials.

Social artefacts: participation and equity by design

The social quadrant now foregrounds *Accessibility & Offline-first UI* and *Care-giver proxy access*. Large-text modes, local caching, and a two-tap logging workflow align with U.S. Office of the National Coordinator (ONC) recommendations for inclusive patient-

facing health IT, ensuring that rural users and older adults remain engaged even when connectivity or digital literacy is limited. Formal proxy accounts enable authorised relatives to enter or review data under their own credentials, a practice associated with higher portal adoption among frail or cognitively burdened patients.

Chat, multi-media sharing, and auto-reporting retain their original functions but now feed a refined *alert and notification* engine. Each alert carries an explanation generated by the platform's explainable-AI layer, thereby satisfying Article 22 GDPR requirements for "meaningful information about the logic involved" in any automated decision. Together, these social artefacts scaffold a digitally inclusive environment that promotes sustained participation while maintaining legal transparency.

Knowledge artefacts: from data to explainable insight

The knowledge quadrant integrates four critical additions:

- Predictive-risk dashboard for clinicians. Built with SMART-on-FHIR widgets, the dashboard streams patient-reported outcomes (PROs) and wearable metrics directly into the electronic health record (EHR), eliminating the need for parallel portals and allowing oncologists to act on new information within the workflow they already use.
- Data-provenance and versioning service. Every model update, training dataset, and parameter change is time-stamped, thereby supporting post-market surveillance and reproducibility—capabilities explicitly called for in the FDA's AI/ML Software-as-a-Medical-Device (SaMD) Action Plan.
- Diagnosis & mental-health guidance. A digital cognitive behavioural therapy (CBT) workbook and mood diary respond to evidence that CBT, integrated with activity pacing, mitigates cancer-related fatigue and depression.
- Virtual-reality (VR) apps & adapter. An adaptor layer lets approved VR modules deliver distraction therapy when pain or anxiety scores surge; randomised trials report clinically significant reductions in pain among hospitalised cancer patients using immersive VR.

These components turn static content (*Symptoms-management information, Health IoTs info., Personalised treatment*) into a dynamic, provenance-tracked knowledge engine capable of producing individualised, explainable, and actionable recommendations.

Status & geo-location artefacts: continuous, contextual sensing

The *wearable-device adaptor* abstracts vendor-specific APIs so that data from fitness bands, smart rings, or continuous-temperature patches populate the *remote-monitoring, vital-data-collection, and tracking* modules without code refactoring. Pilot trials in breast cancer radiotherapy cohorts have shown both technical feasibility and clinical relevance of such continuous monitoring, correlating step counts and heart-rate variability with fatigue trajectories.

Self-diagnosis logic blends sensor trends with daily PROs to generate just-in-time queries ("Your activity has fallen 40% below baseline—are you experiencing increased fatigue?"). With explicit consent, geo-location data can route red-flag patients to the nearest infusion suite or emergency provider, transforming tracking into a safety net rather than a surveillance risk.

Technical artefacts: governance, security, and interoperability

The technical quadrant now embeds:

- Ethical & regulatory-compliance module and transversal compliance layer. These components orchestrate informed consent workflows, enforce retention schedules, and log every data access or algorithmic recommendation, thereby operationalising GDPR and HIPAA mandates and enabling regulator auditability.

- **Explainable-AI service.** Each model output includes a human-readable rationale (“Neuropathy risk ↑ because activity ↓ and numbness reported ×3 days”), addressing widespread concerns about algorithmic opacity in oncology decision support.
- **Interoperability & Integration framework.** SMART-on-FHIR APIs export data to EHRs, pharmacy systems, and payer platforms, while multi-factor security governs authentication across stakeholders. Prior demonstrations of SMART-on-FHIR PRO apps confirm that such integration can be achieved with negligible clinician burden.
- **Big-data infrastructure.** De-identified, longitudinal datasets underpin continuous model retraining and health-services research, with the versioning service ensuring that each analytical result is reproducible.

Stakeholder alignment

Patients receive personalised, explainable guidance and can delegate data entry to proxies when treatment-related fatigue is overwhelming. *Support networks* gain secure chat and multimedia channels to reinforce adherence. *Physicians and pharmacists* obtain real-time dashboards and VR-therapy eligibility flags inside the EHR, facilitating rapid medication adjustments. *Insurers* access provenance-tracked outcomes for value-based payment models, while *regulators* audit algorithm versions and consent logs through the compliance layer.

This conceptual design directly addresses the earlier identified gaps:

Interoperability & Integration: by having a clinician-facing component and aligning data with standards, we close the loop with healthcare providers.

Personalization & AI: by including an analytics engine that learns from the data and tailors content/alerts, we move beyond static logging to intelligent support.

User engagement: by providing peer support and easy logging, we aim to keep patients engaged daily, which is crucial for long-term efficacy.

Digital equity: by involving caregivers (with permission) and focusing on simplicity, we ensure patients who need help using the app can still benefit (a caregiver might enter data on their behalf or at least remind them). Also, the app could have a feature to print out a summary (for those who prefer paper or to bring to appointments physically).

Figure 6 depicts a five-stage closed-loop workflow in which through the conceptualised app, the patient *captures* a symptom that the analytics engine immediately *analyses* to update trends and predict risk. When a threshold is breached, the system *responds* by alerting the clinician dashboard and simultaneously *empowering* the user with a CBT breathing exercise and, where available, a VR guided-movement session.

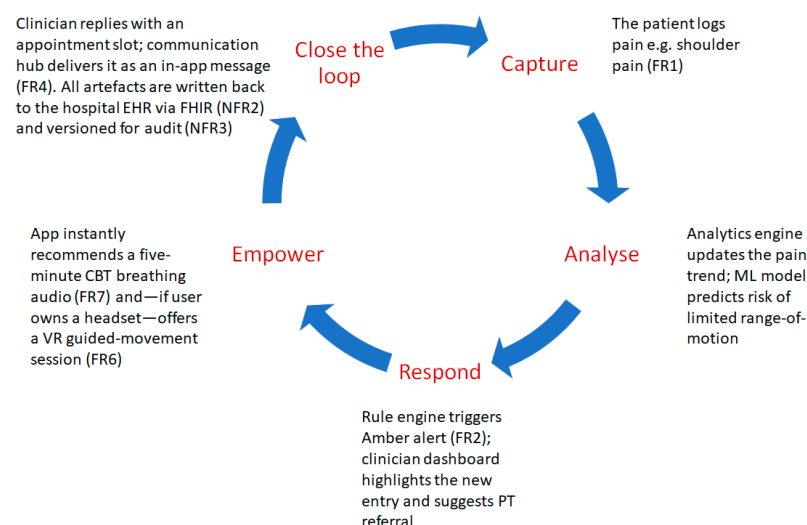


Figure 6. Closing the loop with mobile app ecosystem.

The clinician's appointment offer is delivered in-app and, together with every artefact generated in the cycle, is written back to the EHR via FHIR and versioned for audit, thereby *closing the loop*.

Taken together, these elements transform the app from the “logging-and-learn” paradigm that dominates current offerings into a holistic, personalised, and clinically integrated companion, one that anticipates problems, supports the whole person, and fits seamlessly into modern cancer care. We anticipate that implementing such a design would differentiate future breast cancer apps from the current generation, offering real-time connectivity with care teams, adaptive guidance, and robust support, thereby significantly improving patient outcomes and experience.

7. Discussion

This study set out to (1) consolidate an evidence-based set of functional and non-functional requirements for breast cancer symptom-management (BC-SM) apps and (2) benchmark leading commercial products against those requirements. Our analysis confirms that digital self-management can translate trial-proven symptom-monitoring benefits into routine care yet also shows that the current marketplace still falls short on several critical dimensions.

7.1. What Today's Evidence Tells Us

Randomised and quasi-experimental trials consistently demonstrate that mobile logging of patient-reported outcomes (PROs) reduces acute toxicity, distress and unplanned admissions. Landmark studies such as Basch et al. [19] on general oncology, Egbringer et al. [22] on diary-based chemotherapy support and Graetz et al. [23] on EHR-linked alerts all showed faster clinical response and better functional status than usual care. Breast-cancer-specific trials—e.g., Interaktor [8], mPRO Mamma [9] and e-Symptom Tracker [49]—replicate these gains, reporting 15–40% relative reductions in nausea, pain or global distress. Recent work also extends benefits to psychosocial domains: an “intelligent follow-up” app halved fear-of-recurrence in young survivors [63], while Park et al.'s [65] quasi-experiment linked AI coaching to lower symptom-cluster scores.

7.2. Strengths in the Current Commercial Offer

Our marketplace scan shows that core diary and education functions are now commoditised. All five evaluated apps provide multi-symptom sliders, medication reminders and a searchable knowledge library, and four score $\geq 4/5$ for usability on the Mobile App Rating Scale. These findings align with user-experience reports from large survivor cohorts, where 69% of patients already rely on smartphones for daily disease-management tasks. Continuous optimisation of front-end design has clearly paid off: compliance rates of $\geq 75\%$ observed in recent usability trials [59] match or exceed those achieved by earlier paper diaries.

7.3. Persistent Capability Gaps

Despite these gains, four high-impact requirements remain poorly supported:

Interoperability and clinico-digital feedback loops: Only Owise exports structured data (HL7 FHIR) into hospital EHRs, mirroring the “SMART cancer navigator” architecture advocated by Warner et al. [78]. Without such integration, clinicians must either ignore patient-generated data or juggle stand-alone dashboards—a burden that stifles adoption and sustainable reimbursement [19,80].

Real-time clinician alerts: Randomised evidence indicates that threshold e-alerts cut high-grade toxicity by up to 50% [23], yet only one of the five commercial apps offers a fully automated escalation pathway.

Personalisation & AI: Early prototypes show that machine-learning models can forecast chemotherapy-related toxicity [62], but current consumer apps remain purely descriptive. Where “AI” is claimed it is typically rule-based content filtering rather than predictive analytics.

Mental-health and VR modules: Psychosocial distress can amplify physical symptom burden, but none of the benchmarked apps embeds validated CBT, mindfulness or VR distraction components despite meta-analytic evidence of benefit [52,60].

7.4. Equity and Accessibility Issues

Moon et al.’s [42] longitudinal UK cohort reveals that one in five survivors still lacks a smart device or the confidence to self-manage digitally. Age, rurality and deprivation strongly predict non-use. This digital divide matters because integrated care systems increasingly discharge low-risk patients into Patient-Initiated Follow-Up (PIFU) pathways [5,6]. If BC-SM apps become the default data channel, inequitable access could widen outcome disparities. To mitigate this risk, future designs must include offline caching, large-text modes, and formal carer-proxy accounts, and must be accompanied by blended training.

7.5. Data Privacy and Regulatory Considerations

Trust is a prerequisite for sustained uptake. All apps in our sample met baseline encryption and authentication standards, but none supplies the transparent model-explanation now recommended for AI Software-as-a-Medical-Device (SaMD) submissions. As algorithms progress from static triage to adaptive prediction, explainable-AI overlays and versioned audit trails will be essential to maintain GDPR/FDA compliance and clinician confidence [33].

7.6. Design Implications

Our requirement hierarchy emphasises three mutually reinforcing service goals—*Capture, Respond* and *Empower*. To meet them, next-generation BC-SM platforms should:

1. **Adopt bidirectional SMART-on-FHIR connectors** so that symptom streams, alert acknowledgements and treatment tweaks are automatically written back to the clinical record.
2. **Embed configurable, nurse-led escalation logic** mapped to CTCAE grades, thereby aligning digital triage with existing oncology governance.
3. **Incorporate modular mental-health toolkits** (mood diary plus short CBT or mindfulness mini-courses) and optional VR “distraction sessions” for pain/fatigue peaks.
4. **Deploy validated predictive models** (e.g., neuropathy risk within next cycle) blended with explainable visual summaries to preserve clinician trust and user agency.
5. **Build for inclusivity**—two-tap data entry, multi-language support, dark mode, and carer delegation; rigorous user-testing with older and socio-economically diverse survivors will be indispensable.

7.7. Limitation and Summary

First, our appraisal of commercial apps relied on publicly available features and limited bench-testing; some capabilities may reside behind institutional licences. Second, evidence-weightings in Table 3 reflect publication volume, which can over-represent popular features rather than unmet needs. Finally, the reference list was updated through database queries but was not re-checked with original authors; residual omissions are possible. In short, BC-SM apps have matured from proof-of-concept diaries to usable companions that ease routine self-care. Their next evolutionary leap must focus on seamless EHR integration,

intelligent personalisation and holistic (physical-plus-psychological) support. Doing so will not only close demonstrable outcome gaps but also future-proof digital oncology against widening service pressures and patient diversity.

8. Conclusions and Future Work

Mobile apps are now an indispensable component of supported self-management pathways for early-stage breast-cancer survivors, yet the ecosystem remains fragmented. By synthesising 19 empirical studies and benchmarking five high-visibility products, this paper delivers three firm conclusions:

- Evidence-backed requirements are known and achievable. Multi-symptom diaries, threshold alerts, context-sensitive education, two-way messaging and user-centred usability standards already demonstrate clinical and experiential benefit across at least five RCTs and multiple cohort studies.
- Commercial offerings still miss the features that matter most to clinicians. Real-time EHR integration, predictive analytics and psychosocial modules are either absent or immature, curtailing both clinical adoption and long-term patient engagement.
- Closing these gaps is technically feasible but demands cross-sector alignment. Interoperability standards (FHIR/SMART), SaMD-level quality management and co-design with digitally marginalised groups provide a ready blueprint; the remaining barriers are organisational rather than technological.

Future work will therefore move beyond static requirement catalogues to *operational prototypes* and *implementation science*. Our immediate agenda is to:

- Build a SMART-on-FHIR pilot that streams PROs into an oncology EHR and returns automated triage advice, with nurse escalation, within a single workflow.
- Integrate a hybrid AI engine that couples a validated toxicity-prediction model with rule-based behavioural nudges, wrapped in an explainable dashboard for both patients and clinicians.
- Embed a tiered mental-health suite, combining a five-item mood screener, CBT micro-sessions and optional VR distraction, and evaluate impact on HADS and fatigue scores in a six-month mixed-methods trial.
- Conduct a digital-equity field study in partnership with community oncology centres to test proxy-access, offline caching and language-localisation features among older and rural populations.
- Prepare a regulatory pathway under UK MHRA Software Group IIb and FDA SaMD guidelines, including continuous post-market algorithm surveillance.

Achieving these goals will transform BC-SM apps from passive logbooks into proactive, learning companions that close the information gap between clinic visits, personalise support and, ultimately, improve survivorship outcomes.

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