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DIGITAL TRANSFORMATION IN ONCOLOGY: EUROPEAN APPROACHES TO REDUCING TREATMENT DELAYS

ABSTRACT

Cancer remains a leading cause of mortality worldwide. The European Cancer Plan (2021) and advances in personalized medicine and digital healthcare have improved detection and treatment. However, delays persist: each month of delay increases mortality risk by 10%; late diagnosis raises costs and reduces efficacy.

Delays stem from patient factors (low health literacy, socioeconomic barriers, fear), infrastructural issues (equipment and specialist shortages), and systemic problems (fragmented pathways, bureaucratic hurdles, inconsistent reimbursement), creating public-private inequalities.

Digital tools – integrated referral/tracking systems, AI diagnostic support, wearable monitors, telemedicine, and remote trials, can streamline pathways, reduce travel, and expedite care. Yet regulatory, technical, and organizational barriers impede adoption.

Ireland's National Cancer Information System and the EU Digital Europe programme illustrate the need for interoperable, secure, user-centred solutions with standardized processes and transparent wait-time reporting.

Timely, equitable oncology care in Europe requires coordinated policies, multidisciplinary collaboration, and digital infrastructure to cut delays, improve survival, and narrow inequalities.

KEYWORDS: digital health care, delays in cancer treatment, telemedicine, artificial intelligence in oncology, health inequalities

JEL: I11, I18, O33, L86, C88

INTRODUCTION

Cancer remains one of the leading causes of death worldwide accounting for nearly 10 million deaths in 2020. Early diagnosis and timely treatment have a profound impact on survival rates. Nevertheless, a number of challenges impede prompt intervention, including disparities in health-care infrastructure, shortages of medical personnel, inefficient patient-referral pathways, and socio-economic barriers. Addressing these issues requires a comprehensive approach that integrates technological innovation, policy reform, and optimized clinical workflows.

Since the launch of the European Cancer Plan in 2021, oncology care has undergone rapid transformation driven by advances in digital health, personalized medicine, and improved care

coordination. These innovations have enhanced early detection, diagnostic accuracy, and access to treatment. Yet significant delays continue to occur at every stage – from the first suspicion of cancer to initiation of therapy, which can have serious consequences for patients. Studies indicate that each month of treatment delay increases mortality risk by roughly 10%, while late diagnosis incurs higher healthcare costs and reduces overall survival. Reducing these delays is therefore critical to optimizing oncology care, ensuring timely intervention, and narrowing health-care inequities across Europe.

Despite national and regional efforts to streamline oncology services, substantial variation persists in patient access, diagnostic speed, and treatment coordination. Factors contributing to delays include both structural inefficiencies – limited diagnostic infrastructure, shortages of specialists, and complex reimbursement procedures – and socio-economic or geographic barriers that disproportionately affect underserved populations. Access to cancer care varies widely across European countries: colorectal-cancer screening rates in 2021 reached 79.4% in Finland, 3.6% in Bulgaria, and under 3% in Hungary (European Cancer Organisation, n.d.; European Commission, n.d.). Similar disparities exist in diagnostic capacity; for example, Iceland has nearly five CT scanners per 100,000 inhabitants, while Hungary has fewer than one (European Cancer Organisation, n.d.). Such discrepancies underscore the need for harmonized policies and targeted interventions to reduce waiting times and improve equitable access to oncology services.

Digitalization of cancer care is increasingly recognized as a key enabler of efficiency gains. Digitized referral systems, artificial-intelligence-driven diagnostics, and real-time data integration can enhance treatment coordination, reduce administrative burdens, and facilitate earlier intervention. However, fragmented digital infrastructure and interoperability gaps among health systems hinder progress. Overcoming these obstacles requires close collaboration among clinicians, researchers, policymakers, and technology innovators to develop comprehensive solutions that prioritize operational interoperability, patient-data security, and equitable access to care.

This article examines the complex nature of treatment delays in oncology, the role of digital technologies and policy initiatives in streamlining patient pathways, and the imperative to address health inequities in Europe. By adopting best practices in care coordination, integrating digital solutions, and fostering multidisciplinary collaboration, health systems can move toward a model in which every patient, regardless of location or socio-economic status, receives timely, high-quality cancer treatment.

1. THE ROLE OF DIGITAL TRANSFORMATION IN REDUCING TREATMENT DELAYS

Effective digital solutions must encompass the entire oncology care continuum – from mitigating the risk of delayed diagnosis to providing comprehensive support for patients at every stage of their disease. Rather than fragmented clinical interventions, the emphasis should be on continuous care that addresses each patient's unique needs and the evolving dynamics of their condition.

Digital technologies ought to be appraised over the long term, as their effectiveness may shift with disease progression. They must also be designed to deliver personalized and culturally adapted care, ensuring that every individual receives treatment tailored to their circumstances. Moreover, the needs of caregivers and family members – particularly during advanced stages and end-of-life care – should be taken into account.

To place the patient at the center of care, digital solutions must balance robust data privacy protections with seamless information sharing. Health-care delivery models should evolve from hospital-centric approaches toward integrated, on-demand care accessible irrespective of a patient's location.

Digitized clinical-decision support systems have the potential to streamline oncology pathways by optimizing decision-making, reducing costs, and eliminating disparities in treatment quality between leading cancer centers and local facilities. Automated data-management tools embedded in electronic health records can accelerate workflows, enhance clinician efficiency and satisfaction, and minimize the risk of error.

For these innovations to succeed, they must meet both patient needs and health-care professionals' requirements. For example, when deploying biometric monitoring technologies, it is crucial first to define which metrics will be measured and how that data will inform care. In geriatric oncology, such tools can assess overall physical function, track adverse reactions, and monitor patients' functional status between visits.

Metrics must be clinically meaningful to patients. Cancer-related cachexia profoundly impacts quality of life, treatment options, and prognosis. While physical activity is a useful endpoint in clinical trials, traditional measurement methods are often complex, costly, and inconvenient. Digital technologies offer simpler, more accessible alternatives – studies indicate that most patients accept wearing small activity sensors as part of their treatment, and that step counts correlate with energy expenditure and quality of life in advanced-stage cancer (European Cancer Organisation, n.d.).

Furthermore, digital tools can boost clinical-trial participation. In a survey of over 1,100 cancer patients, 85% said they would join a trial if remote technologies reduced time and travel burdens; 67% would participate if experimental drugs could be administered intravenously in a convenient setting; and 82% would enrol if wearable devices enabled remote data collection (European Cancer Organisation, n.d.).

Integrating digital solutions into oncology care can markedly improve patient-pathway coordination by reducing diagnostic and treatment delays, enhancing therapeutic efficiency, and improving quality of life.

Delays in cancer treatment profoundly affect survival rates and overall health-care outcomes. A large body of research underscores that even short postponements in initiating therapy can increase mortality across various cancer types. The principal contributors to treatment delays can be grouped into three categories:

- **Patient-related factors.** Delays often stem from a lack of awareness, socio-economic barriers, and fear associated with a cancer diagnosis. Many patients postpone seeking medical help due to financial hardship, limited access to care, or psychological stress. Additionally, low health literacy means some individuals fail to recognize early warning signs, resulting in later-stage diagnoses and reduced treatment efficacy.
- **Infrastructural constraints.** Variations in health-care infrastructure play a significant role in treatment delays. Resource-limited settings frequently face shortages of diagnostic equipment, insufficient numbers of specialized personnel, and long waits for consultations and procedures. Deficits in key diagnostic tools – such as CT scanners and biomarker-testing facilities – further prolong the time to effective treatment initiation.

- **Systemic inefficiencies.** Within health systems, complex referral pathways, bureaucratic hurdles in therapy approval, and inconsistent reimbursement policies create barriers that delay cancer treatment. Moreover, disparities between public and private sectors lead to unequal access, with patients in public systems typically experiencing considerably longer wait times than those in private care.

Digitalization is increasingly recognized as vital for optimizing oncology services, especially in reducing treatment-waiting times. Europe's shortage of medical specialists heightens provider workloads, increasing the risks of fatigue, burnout, and medical errors – including medication mistakes.

Table 1. Consequences of Delayed Cancer Treatment

Consequences of Delayed Treatment	Description
Increased tumor progression and reduced treatment efficacy	Delaying treatment leads to more aggressive cancer growth and reduces the effectiveness of therapeutic interventions.
Higher mortality	Late diagnosis and untimely initiation of treatment increase the risk of fatal outcomes.
Greater emotional and psychological stress	Patients and their families experience heightened anxiety, fear, and uncertainty due to treatment delays.
Increased economic burden on healthcare systems	Treating advanced-stage cancer is significantly more expensive than early intervention, thereby increasing healthcare costs.

Source: own

The implementation of digital systems in oncology care can substantially reduce these risks by improving the coordination of medical processes and enhancing patient safety.

1.1. EUROPEAN STANDARDS AND IMPLEMENTATION OF DIGITAL SYSTEMS

One of the primary standards established by the emerging European Network of Comprehensive Cancer Centers is the adoption of digital medication management systems. This requirement aims to standardize procedures, reduce patient waiting times, and ensure traceability and accountability throughout the treatment process.

A successful model of digitization is the ONCOptimal project (Optimizing the efficiency of oncology day hospitals) in Spain, which aims to enhance the effectiveness of oncology day hospitals. The incidence of cancer in Spain continues to rise, increasing the demand for outpatient oncology services. Issues such as prolonged waiting times for medication and therapy, inefficient resource use, and prescription errors can delay treatment, increase toxicity, lower survival rates, and reduce patient satisfaction (Fundación para la Excelencia y la Calidad de la Oncología, 2023).

The ONCOptimal project provides recommendations focused on introducing new technologies as the most effective and cost-efficient way to reduce wait times and improve patient safety. Implementation of these recommendations could result in national savings of up to €2 billion, reduce the time from diagnosis to treatment initiation by eight days, and save over 4,500 hours of labor capacity monthly (Fundación para la Excelencia y la Calidad de la Oncología, 2023).

As in many European countries, cancer cases in Spain are increasing rapidly. By 2045, the number of diagnosed patients is expected to grow by over 33%, reaching more than 370,000 individuals. This increase in incidence results in higher demand for care. Day hospitals, which offer diagnostics, testing, and therapy without hospitalization, are the preferred setting for

cancer treatment. However, these facilities face immense pressure and are struggling to meet demand.

Key operational challenges in oncology day hospitals arise at multiple points in the care pathway. First, delays and errors in organizing patient appointments waste valuable resources and postpone the start of therapy. Second, limited laboratory capacity prolongs turnaround times for test results, often forcing unplanned hospital admissions and further deferring treatment. Third, staff shortages reduce the opportunity for direct, face-to-face communication between patients and clinicians, diminishing both satisfaction and safety. Fourth, the lack of an integrated electronic prescribing system prevents seamless coordination of drug orders and administration between healthcare teams and pharmacies – leading to treatment delays, preparation mistakes, and suboptimal resource use. Finally, reliance on manual prescription processes elevates the risk of human error during anticancer drug administration, directly threatening patient safety and treatment effectiveness.

These issues largely stem from inadequate state funding, low staffing levels, and outdated prescribing systems. As a result, patients face treatment delays, lower survival rates, and decreased satisfaction with healthcare services (All.Can, n.d.).

The ONCOptimal study identifies inefficiencies in the prescribing, preparation, and administration of medications. Full digitization of these processes could reduce average patient wait times by eight days and save the Spanish healthcare system over $2 billion. Recommendations include using electronic prescribing systems instead of paper documents, automated mechanisms for real-time drug tracking to replace interdepartmental phone calls, and barcode systems for fast and accurate medication logging by nurses (Fundación para la Excelencia y la Calidad de la Oncología, 2023).

The ONCOptimal project highlights key challenges in oncology care and their impact on patient satisfaction and survival, outlining areas for necessary improvement. It demonstrates that technology implementation is the most effective and economically viable strategy to reduce wait times and enhance patient safety. Digitizing prescription and drug validation systems has significantly lowered adverse drug reactions, shortened waiting periods, and achieved financial savings. Furthermore, it has reduced the time from diagnosis to treatment initiation by eight days and saved 4,795 hours monthly in laboratory administrative processes.

ONCOptimal continues to promote the adoption of its recommendations in day hospitals across Spain. Each facility is expected to tailor the suggestions to its specific needs and implement them gradually. The project also aims to showcase hospitals that have successfully introduced these changes to demonstrate real improvements in efficiency and share best practices with other medical centers.

Additionally, ONCOptimal plans to conduct long-term studies on the impact of its recommendations, including their effects on patient survival and overall hospital efficiency (All.Can, n.d.).

1.2. Digitization of Oncology Information Systems: The Irish Model

Another successful example of effective digitization is Ireland’s National Cancer Information System (NCIS). Launched in 2019 as part of the Government’s e-Health strategy, NCIS aims to integrate all patient information into a single platform. Its core functionalities include

electronic prescribing, digital medical records, management of multidisciplinary team (MDT) meetings, and automated drug administration (Health Service Executive, n.d.).

The NCIS is a unified, national, computerized system that records and stores all cancer-related healthcare data for each patient. This encompasses demographic details (name and address), medical history, cancer diagnosis, treatment options, and systemic anticancer therapy (SACT) administration. The National Cancer Control Programme (NCCP) convened a working group to develop a procurement and implementation framework for NCIS, ensuring optimal and safe delivery of SACT, as well as electronic prescribing and administration of cancer medications in publicly funded hospitals.

Following an EU-wide tender process, the contract to build NCIS was awarded to Becton Dickinson (BD) Austria GmbH. The system was developed collaboratively by BD and its partners, coordinated with the NCIS team and the HSE's Technology and Transformation Division under the guidance of a specialized multidisciplinary steering committee (Health Service Executive, n.d.).

A key feature of NCIS is its "single system" approach, which provides seamless access to patient data across different healthcare facilities. This ensures that clinicians always have accurate, up-to-date information on a patient's status, regardless of the treating hospital. To date, NCIS covers 19 of Ireland's 26 cancer centres, with full rollout expected shortly.

Table 2. Summary of the National Cancer Information System (NCIS)

Category	Details
What is NCIS?	A computerized system that records and stores all cancer-related patient data, including diagnosis and treatment.
Implementation	Phased introduction across all public hospitals providing cancer services – including Children's Health Ireland (CHI) at Crumlin – began in 2019.
Rationale for NCIS	Developed by the National Cancer Control Programme (NCCP) in response to concerns from consultant medical oncologists and other healthcare professionals about patient-safety risks due to lack of information sharing, missing records, and absence of a centralized IT system.
Primary Objective	To deliver a clinical information system supporting oncology and haemato-oncology care nationwide, ensuring comprehensive SACT treatment records.
Key Functionalities	Electronic prescribing and verification of SACT orders; digital MDT coordination; automated tracking of drug dispensing and administration.

Source: Health Service Executive

1.3. Model for Digitized Oncology Care – The Paperless Transformation at Dénia Hospital

Hospital Dénia in Spain stands out as a leading example of a fully digitized oncology centre. Awarded the QH (Quality Healthcare) seal for its innovative health-tech implementation, Dénia has transformed its oncology department into a paperless environment, managing the entire treatment pathway digitally, from prescription to administration. This digital strategy accelerates cancer care processes, enhances operational efficiency, ensures patient safety, and improves coordination among clinical teams.

Dénia's digital strategy is built on two foundational pillars. First, it achieves complete digitization of oncology treatment, ensuring that every step – from prescription generation through drug administration, is managed electronically. This end-to-end digital workflow eliminates paper-based handoffs, minimizes delays, and substantially reduces the administrative burden on nurses and pharmacists. Second, the hospital employs a unified

information system that integrates all patient records into a single, interoperable platform. By consolidating data from disparate applications, this system standardizes clinical processes, strengthens data security, and gives care teams real-time access to vital patient information, thereby enhancing decision making.

As a result of these innovations, Dénia has dramatically shortened the interval between diagnosis and treatment initiation: first-cycle chemotherapy now begins within 24–48 hours of consultation confirmation. This rapid turnaround is enabled by an integrated digital protocol that coordinates prescription scheduling, ancillary medication procurement, nursing workflows, and continuous patient tracking.

The hospital's digital overhaul introduced three key innovations that have transformed oncology care. First, Automated Task Activation ensures that the moment a patient is registered, the system automatically orders laboratory tests, prepares medications, and allocates clinical staff – dramatically reducing administrative burden and accelerating each procedural step. Second, Real-Time Monitoring and Clinical Decision Support gives patient pathway coordinators and physicians continuous access to live treatment data. They can track task completion, monitor patient progress, and trigger additional interventions as needed; critical decisions – such as patient discharge, therapy changes, or protocol initiations, are automatically logged to guarantee seamless continuity of care. Finally, Interoperability and Transparency allow precise measurement of time intervals between all process steps, enabling hospital leadership to pinpoint bottlenecks, optimize workflows, and implement targeted improvements.

During a discussion on Dénia's digital transformation (European Cancer Organisation, n.d.), Grant Caroll emphasized that successful implementation hinges on aligning digital solutions with the real-world workflows of healthcare professionals. He cautioned that introducing overly radical or ill-fitting technologies without accounting for everyday clinical processes may provoke staff resistance and hinder adoption.

Therefore, effective digitization requires technology providers to collaborate closely with hospital teams to design user-centric, efficient digital tools. Dénia's paperless transformation exemplifies the transformative potential of digital technologies in oncology care. Through automation, interoperability, and real-time monitoring, the hospital has successfully reduced delays, optimized treatment, and elevated the quality of patient care. This model can serve as a blueprint for oncology centres worldwide striving for sustainable, digitally enabled cancer services.

Despite the clear advantages, challenges remain. Experts involved in these digitization efforts highlight the need for:

- **Workflow alignment** – Systems must simplify, not complicate, clinicians' and nurses' tasks.
- **Training and resource allocation** – Institutions must dedicate time and funding for staff education.
- **Robust technical support** – Ongoing maintenance and rapid troubleshooting are essential.

Digital transformation holds the promise of reducing treatment delays, enhancing patient safety, and improving healthcare system efficiency. European experiences – illustrated by ONCOptimal, NCIS, and Dénia's initiatives – demonstrate tangible benefits that other systems

can adopt. Full success depends on integrating these technologies into national health strategies, supported by governmental and institutional commitment to widespread implementation.

2. DISCUSSION

The digital revolution – driven by Industry 4.0 and globalization – has fundamentally transformed business practices across sectors, encompassing everything from new business models and smart technologies to big data analytics and integrated value chains (Diniz, Duarte, Amaral, & Pereira, 2021; Kraus et al., 2021). This shift has placed immense pressure on organizations to adapt and innovate to remain competitive. Successful adaptation hinges on the deployment of digital processes and collaborative tools, underscoring the crucial role of digital transformation. In a business context, digital transformation is intimately linked with technologies such as big data, artificial intelligence, and analytics, demonstrating their potential both as drivers and enablers of competitive advantage. Because digital transformation demands continual adjustment to a rapidly evolving and competitive environment, it can be viewed as a catalyst for change that affects all aspects of human life through technology (Donthu et al., 2020; Bruskin et al., 2017).

Despite its promise, healthcare has lagged behind other industries in digital transformation – a trend also evident in oncology care, where integrating digital technologies could enhance cancer diagnosis and treatment. Several factors contribute to this slow uptake. A study by Phichitchaisopa and Naenna (2013), using the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), identified performance expectancy, effort expectancy, and facilitating conditions as key determinants of user behavior.

Other research highlights a number of critical barriers, including regulatory, legal, and policy obstacles introduced by the digital health revolution (Berardi et al., 2024). Skepticism about the effectiveness of new technologies (Iyanna et al., 2022) and concerns over service quality and cybersecurity risks (Mumtaz et al., 2023) further impede rapid adoption. Interestingly, non-technological barriers – such as organizational culture, structure, and governance – are frequently cited as the primary hurdles to digital scale-up (Biesdorf & Thomas, 2018).

Nonetheless, healthcare now stands at a pivotal moment: accelerated digital transformation is both essential and achievable through strategic use of both novel and existing technologies. In Bulgaria, oncology care is likewise modernizing via telemedicine and digital medical record systems, which facilitate access to high quality treatment. Healthcare organizations possess a unique advantage here – they can learn from both the successes and failures of more digitally mature industries (Glaser & Shaw, 2022).

The term “digital transformation” is increasingly prevalent in healthcare, especially given rapid technological progress (Rowlands, n.d.). Whereas “digital health” – the use of technology to improve patient care – is relatively well defined, there is no single, universally accepted definition of “digital transformation.” This ambiguity stems from the inherently transformative – and thus theoretically diverse – nature of the term itself.

In Bulgaria, advanced diagnostic and treatment technologies – such as AI driven image analysis and robotic surgery – are boosting precision and therapeutic efficacy, leading to improved patient prognoses. Digital health encompasses the development of ICT in healthcare – from electronic medical records and wearable devices to telemedicine – and is expected to expand into health promotion, prevention, primary care, long term care, and self-management.

Despite varying definitions, common elements emerge: digital transformation in healthcare must be understood as a systemic, complex intervention. From this perspective, it can be defined as a planned change entailing the integration of inherently complex digital tools, which are challenging to implement and evaluate (Hulshof, 2022). Such interventions aim to induce change across the entire system – affecting all organizations and providers, to ultimately enhance healthcare efficiency, quality, and population-level outcomes.

The complexity of digital transformation in healthcare makes it difficult to fully grasp its impact. Yet digital health holds the potential to revolutionize healthcare delivery and experience by enabling remote monitoring, improving disease management, and supporting more personalized treatments. Moreover, patient-generated digital health data can substantially contribute to clinical practice and real-world evidence generation, aligning with the shift toward value and patient-centered care (Khosla et al., 2021). Digital tools can also empower providers to improve care quality and patient outcomes by preventing adverse drug events, enhancing treatment adherence, reducing duplicated testing, and potentially lowering costs (Jones, Peter, Rutter, & Somauroo, n.d.).

Organizations such as the World Health Organization and the European Commission have recognized the benefits of digital health, including greater access, improved quality and safety, and higher efficiency in care delivery (Mumtaz et al., 2023; European Commission, 2021). The EU's Digital Europe programme explicitly supports digital transformation across sectors. The Lancet–Financial Times Commission on Governing Health Futures 2030 similarly underscores the broad impact of digital transformation, suggesting it will soon become the primary lens through which health and wellbeing dynamics are viewed (Kickbusch et al., 2021). Digital technologies are already integral to our lives – directly impacting healthcare via electronic records, telemedicine, and self-monitoring, and indirectly affecting health through social, commercial, and environmental determinants, such as improved patient education and more efficient resource management (Kickbusch et al., 2021).

Today, establishing realistic timeframes for initiating cancer treatment post-diagnosis is a core principle embedded in clinical guidelines, national policies (including cancer plans), and European initiatives like the EU Network of Comprehensive Cancer Centres. Systematic collection and publication of patient waiting time data are essential to identify and address areas for improvement. This aligns with the need for transparent, accountable health systems—a goal Bulgaria shares with other EU member states.

Regarding digitalization, there is strong support for integrating fully functional, connected digital medication management systems within the EU Network of Comprehensive Cancer Centres, following the successful Irish NCIS model. Implementing a similar system in Bulgaria could markedly improve data exchange and care coordination. Effective nationwide digitalization, however, requires standardizing hospital processes – a task demanding dedicated resources and effort. Furthermore, digital systems must enhance transparency around treatment timelines to enable better management of bottlenecks and delays. Crucially, technology vendors must prioritize healthcare professionals' workflows to ensure user adoption and avoid disruptive rollouts, especially in Bulgaria, where existing digital infrastructure and training levels vary across institutions.

CONCLUSION

The future of healthcare lies in a dynamic environment characterized by rapid technological advances, evolving patient needs, and transformative innovations. This chapter has explored

key trends and forecasts shaping the industry, including AI integration, telemedicine, genomics, and patient empowerment. These shifts promise a healthcare ecosystem that is more efficient, accessible, and personalized than ever before. However, they also present challenges, such as data privacy, ethical considerations, and equitable access. Navigating this evolving landscape will require a careful balance between innovation and ethical practice, ensuring that the future of healthcare benefits all segments of society.

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