Technological Surveillance of Digital Applications in the Care of Oncology Patients: Current State and Perspectives

Vigilancia Tecnológica de las Aplicaciones Digitales en el Cuidado de Pacientes Oncológicos: Estado Actual y Perspectivas

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Abstract

Introduction— Digital technologies applied to cancer diagnosis, prognosis, and treatment have become a new strategy for providing better care to patients with this disease and improving their quality of life.

Objective— This review aims to identify the main concepts associated with digital technologies currently at the forefront of cancer treatments that support medical processes in this field.

Methodology— An initial search was conducted in PubMed (www.ncbi.nlm.nih.gov/pubmed) and www.ClinicalTrials.gov for terms related to digital health technologies. An exploration of existing and recent studies on digital technologies in the field of cancer followed this. After selecting the technologies, a further literature search was conducted to detail the concepts associated with each technology.

Results— Various digital technologies applied in cancer were identified, along with significant projects in each area. These demonstrate the viability of the applications developed from these technologies at different treatment stages for cancer patients.

Conclusions— Among current health technologies, telemedicine is emerging as one of the most promising options for cancer treatment. In Colombia, telemedicine requires further development and research to realize its potential as a future cornerstone of healthcare.

Keywords— Cancer; digital technologies; e-health; telemedicine; teleoncology.

Resumen

Introducción— Las tecnologías digitales aplicadas para el diagnóstico, prognosis y tratamiento para el cáncer se han convertido en una nueva estrategia para brindar mejores condiciones de atención a pacientes con este padecimiento y mejorar la calidad de vida de estos.

Objetivo— La revisión realizada tiene como propósito identificar los principales conceptos asociados a tecnologías digitales que en la actualidad se encuentran a la vanguardia en los tratamientos de cáncer y que apoyan los procesos médicos en este ámbito.

Metodología— Inicialmente se realizó una búsqueda en PubMed (www.ncbi.nlm.nih.gov/pubmed) y www.ClinicalTrials.gov de términos relacionados con las tecnologías de salud digital. Posteriormente se realizó una exploración de los estudios existentes y actualizados en cuanto a las tecnologías digitales aplicadas en el ámbito del cáncer. Una vez seleccionadas las tecnologías, se continuó con la búsqueda de la literatura que precisara los conceptos asociados a cada una de estas.

Resultados— Se lograron identificar las diversas tecnologías digitales aplicadas en el cáncer y proyectos significativos en cada una de estas, que demuestran que las aplicaciones desarrolladas a partir de estas tecnologías son viables en las diferentes etapas relacionadas con tratamientos para pacientes que sufren de esta enfermedad.

Conclusiones— De las tecnologías actuales aplicadas a la salud, es claro que la telemedicina se convierte en una de las opciones con mayor proyección y futuro para el tratamiento de cáncer. La telemedicina en Colombia requiere seguir desarrollándose, es necesario que se incentiven investigaciones pues esta herramienta representa un futuro prometedor para la salud.

Palabras clave— Cáncer; tecnologías digitales; e-health; telemedicina; tele oncología.

I. INTRODUCTION

Cancer is the leading cause of death globally, affecting populations regardless of class, age, race, or religion. According to the World Health Organization (WHO), nearly 10 million deaths in 2020 were attributed to this disease [1]. Figure 1 shows the global cancer mortality rate. The types of cancer with the highest death toll in 2020 were lung cancer (1.8 million deaths), colorectal cancer (916,000 deaths), liver cancer (830,000 deaths), gastric cancer (769,000 deaths), and breast cancer (685,000 deaths).

Fig. 1 Global cancer mortality rate.
Fuente: Globocan 2020

As per the Pan American Health Organization, in the Americas, the most commonly diagnosed cancers in men are prostate (8.6%), lung (11.7%), colorectal (10.2%), and bladder (5.9%). For women, the most frequent diagnoses are breast (30.7%), lung (10.3%), colorectal (9.6%), and uterine body (6.4%) cancers. In Latin America and the Caribbean, over 56,000 women were diagnosed with cervical cancer, and more than 28,000 succumbed to it [2]. In Colombia, from January 2, 2020, to January 1, 2021, 416,289 cases of cancer were reported, with 95% being invasive tumors, amounting to 394,575 cases [3].

A patient undergoing cancer treatment faces not only the deterioration of their physical health but also a significant impact on their emotional well-being. These patients often develop feelings unique to their experience, burdening themselves and their families. The failure to detect and alleviate symptoms can cause considerable distress. However, short hospital stays leave little time for symptom management support. Moreover, treatment side effects often worsen after patients are discharged home [4].

Given this scenario, the fight against cancer has become a priority for various governments and is crucial for developing countries. The public health battle against cancer has become increasingly complex due to the disease burden shifting from wealthier to less affluent countries [5]. This underscores the necessity for strategies that provide information, support, and guidance throughout the disease process and enable early diagnosis and effective monitoring of clinical and psychological conditions. Digital technologies represent one such strategy. Patients could greatly benefit from Internet-based support, which extends traditional health services into their homes, aiding them in managing their symptoms and challenges independently of scheduled doctor or hospital visits [4].

Adopting digital technologies in healthcare is now a reality, significantly accelerated by the pandemic, especially in remote care settings. Mass-scale use of digital health technology enables timely assessment and planning by a patient's healthcare team. Effective symptom management through these technologies allows patients to continue their treatment while maintaining a good quality of life [6].

Advances in digital communications and medical technology have led to healthcare digitization [7]. Increased access to and acceptance of these technologies among physicians and patients generate large volumes of data. When integrated with electronic health records, this data becomes crucial to physician decision-making. Patient-level data offer real-world medical insights, opening opportunities for improved clinical decision-making, patient empowerment, better health outcomes, and cost reductions [8].

As we move forward with implementing digital oncology tools, it is essential to do so with careful consideration, using oncology healthcare standards as the foundation for an effective tool. Digital health holds limitless possibilities in cancer care, and oncology staff must lead the way to ensure the success of this initiative for both patients and healthcare workers.

II. RELATED WORKS

This section of the paper highlights research and studies on using digital technologies in cancer diagnostics and treatment. The study referenced in [9] discusses the need to enhance breast cancer risk assessment models. This enhancement would allow for personalized screening strategies that yield a more favorable harm-benefit ratio, offering earlier detection and improved outcomes for breast cancer compared to current screening guidelines. This advancement is facilitated by artificial intelligence (AI), particularly deep learning, which has significantly increased the utility of imaging in predictive models [9].

Additional research on the application of AI in cancer is detailed in [10]. This review focuses on integrating biology with AI and how AI-centric support can assist oncologists in administering precise therapies. A critical aspect of this approach is the identification of new biomarkers that challenge traditional injectable drugs and discovering new medicinal targets to refine treatment methods. The emergence of "next-generation sequencing" (NGS) programs addresses these challenges and has revolutionized the field of "precision oncology" (PO). NGS provides numerous medical capabilities crucial for risk prediction, early diagnosis of infections, identification of sequencing patterns and medical imaging (MI), accurate diagnosis, biomarker detection, and the identification of medicinal targets for medical innovation [10].

The study in [11] is a notable example of cancer prediction using data analytics and artificial intelligence (AI). This research emphasizes using these technologies to predict patient outcomes following colorectal cancer surgery. The study analyzed data from 4,336 colorectal surgery patients between 2003 and 2019. Forty-seven patient parameters were considered, including demographics, perioperative and postoperative outcomes, surgical approaches, complications, and mortality rates. Data analyses were employed to evaluate the significance of each variable, and AI prediction models were developed for length of stay (LOS), readmission, and mortality, achieving accuracies of at least 80% [11].

Another significant study, referenced in [12], demonstrates the application of digital technologies in cancer care. This study aimed to evaluate the feasibility and acceptability of PROMPT-Care (Patient-Reported Outcome Measures for Personalized Treatment and Care), a cutting-edge electronic health (eHealth) system. PROMPT-Care is designed to capture cancer patient-reported outcome (PRO) data, enable data linkage and retrieval to support clinical decision-making and patient self-management and provide data for ongoing evaluation and innovative research [12].

The research presented in [13] introduces another significant study on e-health technologies in cancer care. The Oncokompas e-health self-management application is a fully automated behavioral intervention technology designed to assist cancer patients in actively managing their symptoms. Oncokompas aims to inform patients about their symptom burden and provides information about available supportive care options. This empowers patients to address their symptoms, which is expected to improve functioning and well-being [13].

Concerning video consultation technology, the study in [14] focused on comparing the attitudes and satisfaction levels between colorectal cancer patients and their treating surgeons regarding video consultations in the outpatient surgical care clinic of a tertiary referral center [14].

As part of these emerging technologies, telemedicine plays a crucial role in the follow-up and management of cancer patients. The study [15] aimed to detail telemedicine's historical and legal aspects, explicitly focusing on teleconsultation and tele-oncology and exploring how these technologies shape the landscape of cancer care [15].

III. MATERIALS AND METHODS

To conduct systematic reviews and meta-analyses, the research was carried out using the PRISMA methodology [16]. Key terms related to digital health technology and cancer treatment were used to perform comprehensive searches in PubMed (www.ncbi.nlm.nih.gov/pubmed) and www.ClinicalTrials.gov.

The most important terms included connected devices, smart devices, wearables, activity trackers, sensors, remote monitoring, electronic surveys, electronic patient-reported outcomes, telehealth, telemedicine, artificial intelligence, chatbots, digital assistants, healthcare, and cancer. For a complete list of search terms, please refer to the Data Supplement. Studies were selected according to the PRISMA method through several stages: identification, screening, eligibility, and inclusion. Potential records were identified and selected based on their titles and abstracts. Subsequently, after reviewing the full texts, the eligibility of the studies was assessed, and only those that met the inclusion criteria were included.

The inclusion criteria for recently published studies in this review focused on using digital health technologies in cancer care. Factors considered in selecting these studies included the rigor of the research, endorsements from reputable organizations, the year of publication, and the number of citations. The data extraction involved analyzing the technology used; the population studied the study design, the outcomes, and potential biases identified after selection. This was followed by a conceptual analysis of the leading technologies based on the literature reviewed.

Ultimately, the data were synthesized and presented in tabular and narrative formats. This presentation emphasized the most popular and significant emerging technologies in the field. Each scientific article was thoroughly analyzed to determine the most suitable digital technologies for cancer care.

A. Inclusion and exclusion criteria

Specific inclusion and exclusion criteria were established to ensure the relevance and quality of the included studies. The criteria for acceptance included:

- Research explicitly focuses on the use of digital health technologies in oncology care.
- Recent publications, defined as research published within the last five years, ensure the relevance and timeliness of the information.
- Studies demonstrate a high degree of rigor in their methodology.
- Papers that have been frequently cited in other research indicate their impact and recognition within the field.

The exclusion criteria were as follows:

- Research not directly related to digital health technology or oncology care.
- Publications older than five years to maintain the current relevance of the study.
- Studies need more rigorous methodology or establish transparent methodological practices.

IV. CONTRIBUTIONS Y RESULTS

Digitalized healthcare, encompassing e-health, telemedicine, telemonitoring, and digital therapies, is a significant domain in modern medical practice. The terms ‘digital health,’ ‘telehealth,’ and ‘e-health’ are often used interchangeably, defined as providing health care services supported by telecommunications or digital technology to improve or support health care services.

In Colombia, the realm of e-health, or as it is also known, telehealth, is governed by regulations that have been enacted and progressively updated since 2010. Law 1419 of 2010 laid down the guidelines for the development of telehealth in Colombia [17]. his was followed by Law 1438 of 2011, which mandated the establishment of electronic communication schemes, telemedicine services, assistance, and home care tailored to the country’s conditions [18]. The National Development Plan 2018-2022 further addressed telehealth-related elements, mainly focusing on the interoperability of information systems, enhancing connectivity in remote territories, and articulating with MINTIC guidelines. These guidelines promoted telehealth programs, interoperable electronic medical records, electronic billing, and other ICT appropriations [19]. The most recent significant milestone in the implementation of telehealth in Colombia was Resolution 2654 of 2019, which set forth provisions for telehealth and established parameters for the practice of telemedicine in the country [20].

B. E-health

Globally, e-health solutions are recognized as integral to every stage of the healthcare process, encompassing prevention, diagnosis, decision-making, treatment/intervention, and follow-up. E-health, an emerging field at the intersection of medical informatics, public health, and business, refers to healthcare services and information delivered or enhanced through the Internet and related technologies. More broadly, the term signifies not just a technological advancement but also a mindset, a way of thinking, an attitude, and a commitment to a globally networked approach to improving healthcare at local, regional, and global levels through information and communication technologies [21].

In the context of oncology, using e-health solutions in the care of patients with cancer is becoming increasingly crucial. By enabling real-time, dynamic, technology-assisted assessments and interventions, e-health is critical in optimizing supportive care in oncology as of 2021. Notably, e-health has the potential to enhance communication between patients and healthcare professionals, improve the assessment and management of symptoms and toxicities, and optimize patient engagement throughout the care process [22].

In Colombia, telehealth is defined as a collection of health-related activities, services, and methods conducted remotely with the assistance of ICT, as illustrated in Fig. 2. This includes, among other aspects, Telemedicine and Tele-education in health. The goal is to improve access, resolvability, continuity, and quality of clinical care, impact public health, and enhance health education through ICT [20].

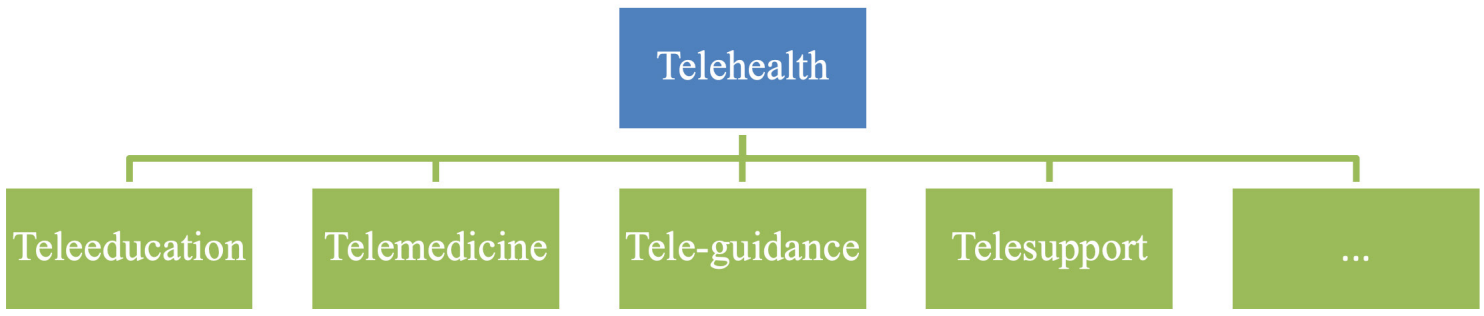

Fig. 2 Telehealth categories in Colombia.
Fuente: Own elaboration with information from Resolution 2654 de 2019

Tele-guidance in healthcare is defined as a series of actions conducted through ICTs to provide users with information, counseling, and advice in various aspects, including promotion, prevention, diagnosis, treatment, rehabilitation, and palliation. Tele-support, on the other hand, refers to the assistance requested by one health professional from another, using ICT within the context of their professional relationship [20].

An important study regarding the application of e-health to cancer care is "User Perception of New E-Health Challenges: Implications for the Care Process." This study aimed to understand the expectations of patients involved in the care processes for 'cervical cancer' and 'pregnancy, childbirth, and puerperium,' particularly regarding online access to their clinical histories and follow-up in the care process. It also analyzed the timeframes involved in the cervical cancer care process, identifying potential improvements in waiting times through digital communication tools. This time analysis was conducted using the Business Intelligence tool Biwer Analytics [23].

From the psychosocial point of view, the publication in [24] evaluates the impact of e-health interventions on caregiver burden, depression, and quality of life of informal cancer caregivers and patients. This paper is a significant contribution to the different situations of affectation of this disease that are not directly related to the physical deterioration of human beings.

In [25], A web-mediated follow-up algorithm was developed based on patient's self-reported symptoms, improving lung cancer patients' overall survival. This method allowed early detection of relapses and improved physical condition when they occurred.

A web-based follow-up system was implemented. Patients who were assigned to the experimental arm used an online platform to record their symptoms once every week and self-rate the severity of their symptoms. An email alert was automatically sent to the patient's responsible oncologist when symptoms matched predefined criteria. This allowed early detection of changes in symptoms and rapid intervention in case of relapse. In addition, the experimental arm enabled bidirectional communication between the patient and the medical team through the online platform, allowing continuous monitoring and personalized care.

In [26], the performance of e-health, particularly within the context of cancer care and supportive care, was evaluated. This study emphasizes that current evaluations of e-health performance predominantly focus on efficiency, often overlooking its potential contributions to organizational efficiency and overall quality of life. The methodology of this study involved a literature review on the performance evaluation of e-health in general, as well as specifically in cancer care and supportive care contexts. Notably, the reviewed studies did not detail specific technologies, as the article's primary aim was to analyze the methods and measures used for evaluating e-health performance rather than focusing on particular technologies.

A notable study, cited in [27], was conducted to evaluate the effects of WebChoice, an interactive, internet-based health communication application, on the well-being of cancer patients. WebChoice enables patients to monitor their symptoms and problems, access personalized information and self-care support, communicate electronically with expert cancer nurses, and participate in electronic forums for group discussions with other patients. This one-year repeated measures randomized controlled trial involved 325 breast and prostate cancer patients in the experimental group, while the control group was provided with URLs to public cancer websites. The study found significant between-group differences in global symptom distress, as measured by the Memorial Symptom Rating Scale (slope estimate, -0.052 [95% confidence interval, -0.101 to -0.004]; $t = 4.42$; $P = .037$). However, secondary outcomes did not show significant differences between the groups. Further analyses indicated that the experimental group showed significant improvement in depression. In contrast, the control group experienced a notable decline in self-efficacy and health-related quality of life.

In [28], a significant contribution of the study is introducing a new measure for assessing musculoskeletal symptoms in hematologic cancer survivors and hematopoietic cell transplantation (HCT) recipients. Until this study, the specific features and characteristics of musculoskeletal symptoms in cancer survivors had not been thoroughly investigated, possibly due to the lack of validated methods for assessing these symptoms in this population. The study introduced a new tool called the Muscle and Joint Measure (MJM) for evaluating these symptoms in patients who have undergone transcranial surgery. The research involved a cross-sectional evaluation of 130 adults, 5 to 20 years post-HCT. The assessment included musculoskeletal symptoms using the MJM and health- and treatment-related quality of life. Four subscales of the MJM, with item factor loadings above 0.5, were identified in the principal component analysis: muscle pain or stiffness (myalgias), joint pain, stiffness or swelling (arthralgias), muscle cramps, and muscle weakness. The MJM total score accounted for 77% of the variance, and the subscales' total score and internal consistency reliabilities ranged from 0.86 to 0.93. Validity was established through correlations with other measures such as the Fatigue Symptom Inventory-90-R, the Fatigue Symptom Inventory, and the Short Form-36 (all with $p < 0.001$).

The realm of e-health solutions applied to cancer patients is continuously expanding and evolving, fostering innovations to enhance patient self-management of symptoms, improve quality of life, and provide utility and peace of mind. The main challenges lie in developing and implementing digital solutions adaptable to a wide range of patients while ensuring patient compliance and adaptability for use in various health systems and living environments [6].

C. Telemedicine

Another category of digital technology solutions in cancer care is telemedicine, which provides medical services remotely to patients by healthcare professionals (HCPs) through telecommunication platforms. Healthcare professionals conduct healthcare activities such as patient assessment, diagnosis, or treatment without requiring an in-person hospital consultation, though the legal status of these consultations can vary across jurisdictions [29].

In Colombia, telemedicine is recognized as providing remote health services encompassing promotion, prevention, diagnosis, treatment, and rehabilitation. These services are delivered by health professionals using information and communication technologies (ICT), enabling the exchange of data to facilitate access and timeliness in service delivery. This is particularly beneficial for populations with limited healthcare availability or access in their geographical areas [20]. Fig. 3 illustrates the different categories of telemedicine as practiced in Colombia.

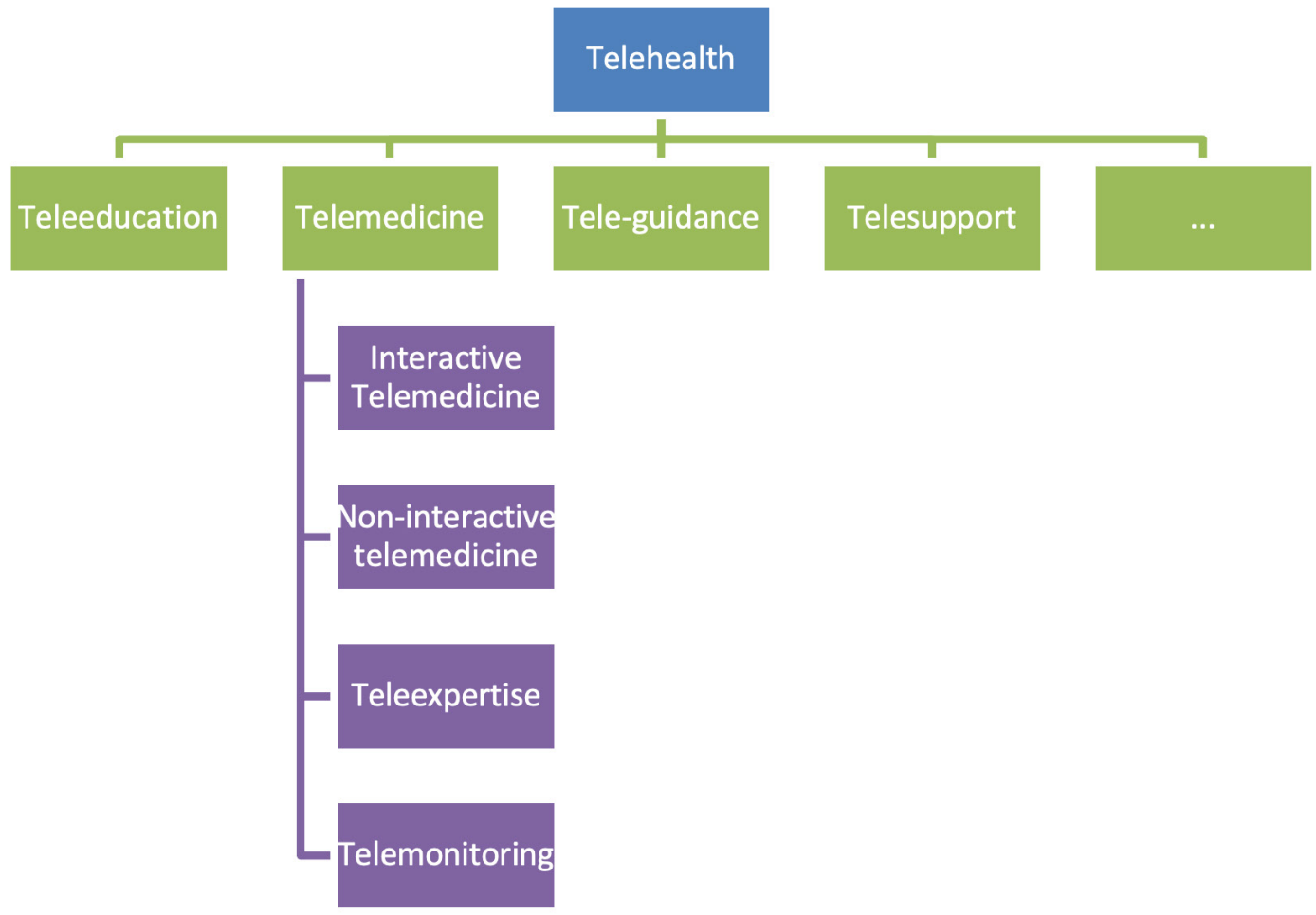

Fig. 3 Telemedicine categories in Colombia.
Fuente: Own elaboration with information from Resolution 2654 de 2019

The healthcare crisis rapidly catalyzed the real-life implementation of digital solutions, including in medical oncology, radiotherapy, and hematology departments. Numerous measures have been introduced to expedite this digital transformation, aiming to integrate telemedicine into everyday clinical practice permanently [15].

Telemedicine is defined as the practice of medicine conducted remotely without the physical presence of the physician [30]. Consequently, tele-oncology provides clinical oncology services from a distance, often facilitated through interactive communication systems [31]. Another vital definition describes tele-oncology as the oncologic application of medical telecommunications, encompassing pathology, radiology, and other related disciplines [32].

Tele-oncology, employed as a strategy for remotely administering procedures and treatments in oncology, has witnessed numerous noteworthy implementations on a global scale. A notable example is the remote application of chemotherapy by the University of Kansas in the United States. For rural cancer patients, frequent travel to major chemotherapy centers can be highly burdensome. This program has successfully implemented remote chemotherapy monitoring by an oncologist, with additional monitoring by an advanced practice nurse, and the administration of drugs by local staff. Interestingly, this approach also allows the rural site to benefit financially from purchasing and administering medications, enhancing the sustainability of this care model [31].

A separate study referenced in [33] focused on understanding practice nurses' views regarding the telemedicine services of a primary care organization in South London. This organization has been offering telemedicine services to patients with chronic obstructive pulmonary disease (COPD) and heart disease for over two and a half years. The study aimed to gather practice nurses' perspectives on these telemedicine services. Descriptive qualitative methods were used to collect data, and semi-structured email interviews were conducted to explore their current experiences with the service and their views on its future. Interviews were held with seven nurses who had an average of 15 months of telemedicine experience and had cared for 34 patients. The nurses generally reported positive experiences with telemedicine but identified barriers to its effective implementation, such as lack of resources, organizational support, patient selection criteria, and technical support. To enhance and ensure the success of telemedicine, they recommended including more team members, increasing training and investment, and expanding the patient selection criteria.

Study [34] focused on evaluating patient and rural health worker satisfaction with a tele-oncology model at the Townsville Cancer Centre in Queensland, Australia. This center has been utilizing videoconferencing since 2007 to provide medical oncology services to rural and remote communities. Accompanied by local physicians and health professionals, 55 patients who received care via videoconferencing from May 2007 to June 2010 participated in a questionnaire-based telephone survey. The survey assessed 16 satisfaction statements using a 5-point Likert scale and included open-ended questions to capture the healthcare workers' perspectives on telemedicine. The participating 50 cancer patients had a median age of 56 years (ranging from 28 to 83 years). Notably, 76% of patients considered the physical examination by local physicians necessary, while the same percentage did not find the presence of local health workers crucial. A significant 78% preferred their initial consultation via videoconferencing to traveling to Townsville. Over 80% of patients agreed with the additional satisfaction statements, and 96% expressed overall satisfaction. Additionally, the study involved 18 healthcare workers whose feedback was generally favorable toward telemedicine.

A study [35] evaluated the use of remote video technology in a home healthcare setting, focusing on quality, utilization, patient satisfaction, and cost savings. This technology facilitated real-time interactions between nurses and patients from different locations, including a video system for cardiopulmonary status assessment. It enabled patients to communicate virtually with healthcare providers from home, eliminating the need for in-person visits. This approach allowed for visual assessment and monitoring of patient conditions, fostering timely interventions and support. Patients had 24-hour access to healthcare providers via the remote video system. The main objectives of this technology were to enhance access to care, improve patient-provider communication, and enable remote monitoring and assessment of health status. It offered a convenient and efficient means for patients to receive home healthcare services without frequent physical visits.

Tele-oncology applications in radiation therapy are well-documented, yet the remote administration of this treatment presents challenges, primarily due to the substantial costs associated with the necessary equipment. To address this, radiation oncologists have developed a tiered system for tele-radiation therapy. This system centralizes more complex treatments at tertiary referral centers while allowing for the planning and implementing simpler treatment protocols at remote centers [36] [37].

Tele-consultation represents another effective form of tele-oncology in cancer treatment. Tele-consultation, a method for transferring medical expertise from hospital environments to primary care settings, is advantageous in managing the intricate home care needs of palliative patients and their families, as noted in [38]. This study evaluating this approach focused on its effectiveness in reducing the symptom burden for palliative care patients at home. The implementation of teleconsultation in this context demonstrates its potential to enhance patient care and support outside of traditional healthcare settings.

Tele-genetics represents a novel application of telemedicine in the realm of cancer care. With advances in research, the increasing availability of genetic testing, and growing public awareness, there has been a surge in demand for cancer genetic counseling services. A pilot study on tele-genetics, including patients counseled for various genetic conditions and cancer susceptibility, revealed a positive influence on medical decision-making and high trust in genetics and neurology providers. The study concluded that telemedicine, by transmitting information, thereby eliminating the need for patient travel, demonstrates its capacity to significantly enhance medical care and surmount the challenges of accessibility and timing often associated with genetic services [39]

On the other hand, Mobile Telemedicine employs mobile applications to capture high-quality images. Its application in oncology, particularly for specific cancer types such as cervical cancer, serves as a complementary tool for visual inspection techniques, notably in the context of African women. [40]

Broadly, tele-oncology platforms enable caregivers, family members in different locations, and specialists who may not be available at the primary cancer center to collaborate and develop a comprehensive care and counseling plan. This approach demonstrates the potential of tele-oncology to facilitate more inclusive and accessible cancer care, transcending geographical and logistical limitations.

D. Tele-monitoring

Tele-monitoring technology is crucial in remote patient care, facilitating frequent or continuous monitoring of patients' vital signs and other symptoms. This technology allows healthcare professionals to evaluate patient data remotely, informing patients and caregivers about necessary actions for effective symptom management and treatment guidance. Additionally, tele-monitoring technologies play a significant role in reducing healthcare-related expenses, which have become a significant burden in modern societies [41].

In the study [42], researchers examined the efficacy of an automated symptom management system called Symptom Care at Home (SCH) in reducing chemotherapy-related symptoms among cancer patients. A total of 358 patients starting chemotherapy were randomized into either the SCH intervention group or the usual care (UC) enhancement group. Participants in the SCH group utilized an automated monitoring system to report the severity of 11 symptoms daily. They received training in automated self-management and had telephone follow-ups for poorly controlled symptoms managed by nurse practitioners (NPs). The NPs used a guideline-based decision support system to provide appropriate interventions. The primary assessment criteria included symptom intensity for each symptom and the number of days with severe, moderate, mild, or no symptoms. Compared with the UC group, patients in the SCH group experienced significantly less severe symptoms. SCH participants saw a 43% reduction in overall symptom burden compared to UC and significant reductions in days with severe and moderate symptoms. Additionally, all symptoms except diarrhea were significantly lower in the SCH group..

A study [43] was conducted to determine if a web-mediated follow-up algorithm could improve overall survival (OS) in patients with advanced-stage lung cancer compared to routine follow-up with CT scans. Following initial treatment, patients with no evidence of disease progression were randomly assigned to either a web-mediated follow-up (experimental arm) or routine follow-up with CT scans (control arm). In the experimental arm, patients weekly assessed their symptoms, triggering an automatic email alert to their oncologist when symptoms met predefined criteria. A total of 133 patients were recruited, with 121 treated as per the intention-to-treat protocol. Most cases (95.1%) were in stage III or IV. The median follow-up period was nine months. The experimental arm exhibited a median OS of 19.0 months, compared to 12.0 months in the control arm, with the hazard ratio indicating a 68% reduction in death risk. Additionally, patients in the experimental arm had a better functional status after their first relapse and were more likely to receive optimal treatment.

The study [44] highlighted the efficacy of tele-monitoring as a tool in cancer patient care, particularly in managing pain. Modern communication tools, such as telemonitoring, have been beneficial for early detection and management of moderate to severe pain, eliminating the need for in-person visits. Patients using telemonitoring reported feeling a closer connection with physicians and better cared for, as monitoring their health data enhanced their self-awareness of their pain [45].

Another innovation in home telemonitoring is developing an interactive voice response (IVR) system, which has been used effectively in healthcare. IVR, with or without short message service (SMS), has shown promising results in the treatment of various conditions, including asthma [46], diabetes mellitus [47], and anticoagulant management [48].

E. Digital therapeutics

Digital therapeutics integrate algorithms based on medical guidelines and best practices to transform collected data into actionable insights. Their primary goal is to augment evidence-based clinical outcomes from clinical studies or real-world evidence. These therapeutics can be employed independently or in combination with drugs,

medical devices, or other treatments to enhance and support medical care. Depending on the risk level of the embedded algorithms, digital therapies may be classified as medical devices. Their regulatory status often determines whether they are available only by prescription (prescription-only digital therapies).

A noteworthy study in digital therapy is STREAM, a therapist-guided, web-based stress management program designed for newly diagnosed cancer patients [49]. The study aimed to assess whether Internet interventions could provide psychological support to patients who often lack in-person support during this crucial time. A total of 129 newly diagnosed cancer patients, 92 of whom were undergoing breast cancer treatment, were randomly assigned to either an intervention group, which utilized the web-based program, or a control group on a waiting list. The primary efficacy endpoint was the assessment of quality of life post-intervention, using the Chronic Illness Therapy Functional Assessment Questionnaire-Fatigue. Secondary endpoints included levels of distress (measured by the Distress Thermometer) and anxiety or depression (measured by the Hospital Anxiety and Depression Scale). Adherence to the program was high, with 80.0% of participants completing six or more of the eight modules. Results indicated that the intervention group experienced a higher quality of life and significantly lower levels of distress post-intervention compared to the control group. However, changes in anxiety or depression in the intention-to-treat population were not statistically significant. The quality of life for the control group improved following the delayed intervention.

Furthermore, in [50], the investigators of this study investigated user characteristics related to the use of various system components of the WebChoice system, a web-based disease management support system for cancer patients, which was analyzed in a large randomized controlled trial involving 325 breast and prostate cancer patients, with a secondary post hoc analysis focusing on 162 cancer patients in the intervention arm. User logs determined usage patterns, and logistic regression identified correlations between patient characteristics and system use. Latent class analysis (LCA) revealed associations between the use of various system elements and factors like social support, symptoms of distress, depression, self-efficacy, and health-related quality of life. Findings showed that around two-thirds of patients actively used WebChoice more than once. The system was prevalent among patients experienced with computers and those without comorbid diseases. The electronic messaging component was frequently used by men with prostate cancer and women with breast cancer who had low social support, significant symptoms of distress, and high levels of depression. Among men with prostate cancer, these factors also correlated with the frequent use of the self-care advice component. Notably, the use of WebChoice varied significantly between men with prostate cancer and women with breast cancer. For women, high usage of all components correlated with low levels of social support, and they reported higher levels of depression than men with prostate cancer. In men, high use of symptom assessments, advice, and discussion forums was associated with elevated levels of symptom distress.

Another significant study [51] focused on the impact of stress on cancer symptom severity and distress post-primary cancer treatment. Mindfulness-based Cancer Recovery (MBCR), a psychosocial intervention incorporating yoga and meditation, has been shown to alleviate pain, stress, and chronic illness symptoms in face-to-face (F2F) settings. However, access to F2F groups is often limited. This study aimed to determine the willingness of underserved patients to participate in and complete an online MBCR program and to assess whether online MBCR offers benefits similar to F2F groups. The study included cancer patients in Alberta who exhibited moderate distress and lacked access to F2F MBCR. Participants were randomly assigned to either a waiting list for an online MBCR group or the next available group, with 64 participants performing online measurements before and after the treatment or waiting period. 47 participants completing or currently engaged in the intervention indicated the study's feasibility. This suggests that a randomized controlled trial of an online MBCR waiting list approach is feasible for reaching underserved cancer survivors. The study explores the potential of online MBCR programs as an effective alternative for those unable to access F2F groups.

These studies collectively demonstrate the potential of web-based interventions in reducing stress and enhancing mental and physical health in cancer patients.

F. Artificial Intelligence

Artificial intelligence (AI) with machine learning capabilities, a key technology within the broader scope of digitized healthcare, can be defined as applying computer algorithms to accurately predict future events based on historical data [52]. The advent of new technologies, particularly those associated with big data and AI, has sparked significant interest in enhancing diagnosis, predicting treatment responses, and more accurately determining the risk of recurrence. This is achieved through the automated analysis of medical records, images, and especially genomic data.

From a health outcomes standpoint, digital health solutions can be categorized based on their connectivity to sensors and ability to capture electronic Patient Reported Outcomes (ePROs). These solutions range from those enabling patient monitoring only to more comprehensive systems that facilitate patient monitoring and symptom management by healthcare professionals. These digital health tools can be particularly beneficial in remote

areas, offering symptom management capabilities directly to patients, with or without real-time decision support for self-management. Patients receiving these services benefit from individualized guidance, which can vary from simple recommendations, like contacting their healthcare provider, to more specific suggestions, such as initiating a particular treatment.

Research [53] has highlighted the potential of deep convolutional neural networks (CNNs) in performing tasks such as classifying fine-grained objects. In this study, researchers demonstrated using CNNs to classify skin lesions from images, using only pixels and disease labels as inputs. A significantly large dataset of 129,450 clinical images covering 2032 different diseases was utilized for training the CNN. The network's performance was evaluated on two crucial binary classification tasks: distinguishing keratinocyte carcinomas from benign seborrheic keratoses and malignant melanomas from benign nevi. These tasks are critical in identifying the most common and deadly forms of skin cancer. The findings revealed that the CNN was on par with dermatologists in both tasks, showcasing the ability of an AI system to classify skin cancer with comparable skill. Additionally, integrating such CNNs into mobile devices could extend dermatological diagnostic care beyond the clinic, offering universal access to vital healthcare at a low cost, in line with the anticipated growth in smartphone usage.

In another study [54], researchers explored the application of deep learning algorithms to whole-slide pathology images, particularly in detecting lymph node metastases in breast cancer patients. This study aimed to assess the efficacy of automated deep-learning algorithms against pathologists' diagnoses. The data for the study came from the CAMELYON16 challenge competition, held between November 2015 and November 2016. Participants were provided a training dataset of whole slide images from two Dutch centers, some with and some without lymph node metastases confirmed by immunohistochemical staining. The algorithms developed were then tested on an independent set of 129 whole slide images. The performance of these algorithms varied, with an AUC range of 0.556 to 0.994. Remarkably, the most efficient algorithm achieved a low false-positive rate and matched the true positive rate of a pathologist without time constraints (72.4%). The most advanced algorithm significantly outperformed pathologists in a diagnostic simulation exercise (mean AUC of 0.810) with an AUC of 0.994. The top five algorithms had an average AUC of 0.960, comparable to an expert pathologist interpreting slides without time constraints. These results suggest that in a challenging competition setting, some deep learning algorithms surpassed the performance of a panel of pathologists in a routine pathology workflow simulation. The findings also demonstrate that the algorithms' performance was akin to an experienced pathologist interpreting whole slide images without time limits. The clinical applicability of these methods requires further evaluation in a real-world clinical context.

In the study [55] researchers addressed the challenge of integrating multi-omics data to predict survival subgroups in patients with hepatocellular carcinoma (HCC). They developed a deep learning (DL) based model to differentiate between robust survival subpopulations among HCC patients across cohorts. The study utilized data from The Cancer Genome Atlas (TCGA), which included RNA sequencing (RNA-Seq), miRNA sequencing (miRNA-Seq), and methylation data from 360 HCC patients. The DL-based model was trained to predict HCC prognosis using this multiomics dataset. The model's performance was compared to an alternative model considering genomic and clinical data. The results showed that the DL-based model's prognostic prediction was comparable to that of the alternative model, demonstrating the efficacy of the DL approach in survival prediction. The DL-based model identified two distinct patient groups with significantly different survival outcomes. The more aggressive subtype was characterized by frequent TP53 inactivating mutations, increased expression of stem markers (KRT19 and EPCAM), elevated levels of the BIRC5 tumor marker, and activation of the Wnt and Akt signaling pathways. These findings highlighted key molecular features associated with differential survival in HCC.

These studies exemplify how artificial intelligence and deep learning are being leveraged to advance cancer classification, metastasis detection, survival prediction, and more, showcasing significant strides in oncology.

V. CONCLUSIONS

Telehealth, or e-health, encompasses a range of health-related activities, services, and methods conducted remotely with the assistance of Information and Communication Technologies (ICT). It is broadly categorized into tele-education, telemedicine, tele-counseling, and tele-support. Telemedicine involves the remote delivery of health services in aspects such as promotion, prevention, diagnosis, treatment, and rehabilitation. Health professionals utilize ICT to exchange data, facilitating easier access and timeliness in providing services, especially to populations facing limitations in service availability or access within their geographical area. In Colombia, telemedicine is subdivided into interactive, non-interactive, tele-expert, and tele-monitoring. A specific branch of telemedicine is tele-oncology, which refers to the application of medical telecommunications in oncology, encompassing fields like pathology, radiology, and other related disciplines. The development of telemedicine in Colombia, par-

ticularly tele-oncology, is ongoing and requires further research and enhancement. This tool is seen as holding significant promise for the future of healthcare in the region, offering potential improvements in access and quality of medical services.

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