Journal of Healthcare Leadership Dovepress

Open Access Full Text Article

EXPERT OPINION

Digital Health Technology & Cancer Care: Conceptual Framework Leading Comprehensive Fruitfulness

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Video abstract

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Abstract: Digital technologies are now integral to daily life. However, their applications for the health of populations remain largely untapped. Increasing cancer incidence, and it being the leading cause of death in every country in the world, justifies the need for increasing healthcare. Digital health technology is a promising field. Digital health means different things to different people. Thus, the need for a concrete, distinctive, comprehensive action plan. Conceptual frameworks represent ways of thinking about a problem and how complex things work. We elaborate on the latest evidence with examples for the role of Digital Health Technology (DHT) as a comprehensive multi-faceted 'Conceptual Framework −5Ps' comprising: (i) DHT for Proper assessment: right from history taking to digital biopsies. (ii) DHT for Pertinent treatment: including genomic data analysis for precision treatment. Artificial Intelligence-based digital pathology approaches are practical and are increasingly improving selective cancer treatments. Digital self-management interventions improve symptom outcomes in adult cancer patients. Digital health can help cancer patients gain more autonomy, self-acceptance, and personal growth. (iii) DHT for Progress monitoring: comprehensively and remotely. The concept "hospital at home" feasible with DHT. (iv) DHT for Prevention applications: reaching all rewardingly. (v) DHT for Professional standards: education excellence. Proficiency is desirable when using DHTs fast-advancing applications. Doctors may not have the information they need to use a given DHT. General Medical Council, UK, and Medical Council India have been proactive in technology training. Regulations & ethics rigour are required energetically. All new technologies must meet the same bar for clinical evidence as other clinical interventions. Digital Health Academy is required to meet the highest standards, energizing and ensuring excellence. In the current state of healthcare and growing demands, good developments in DHT seem the solution. A conceptual framework is a good start for generous success. We hope our work progresses mindsets, practices, and policies majorly.

Plain Language Summary:

Winning wars against cancer requires highest practical professionalism holistic, which is presented as:

- The cancer incidence is increasing. It is the leading cause of death in every country in the world. All this is alarming!
- Delivery of care is important. Currently, even advanced countries grapple with growing disparities in cancer-related outcomes between their rural/urban/suburban populations.

Doctors' intelligence assisted with Artificial Intelligence to enhance patient care and augment clinical practice is a tactful useful trend.

Digital Health Technology (DHT) for improving access to care is a promising field with favourable potentials.

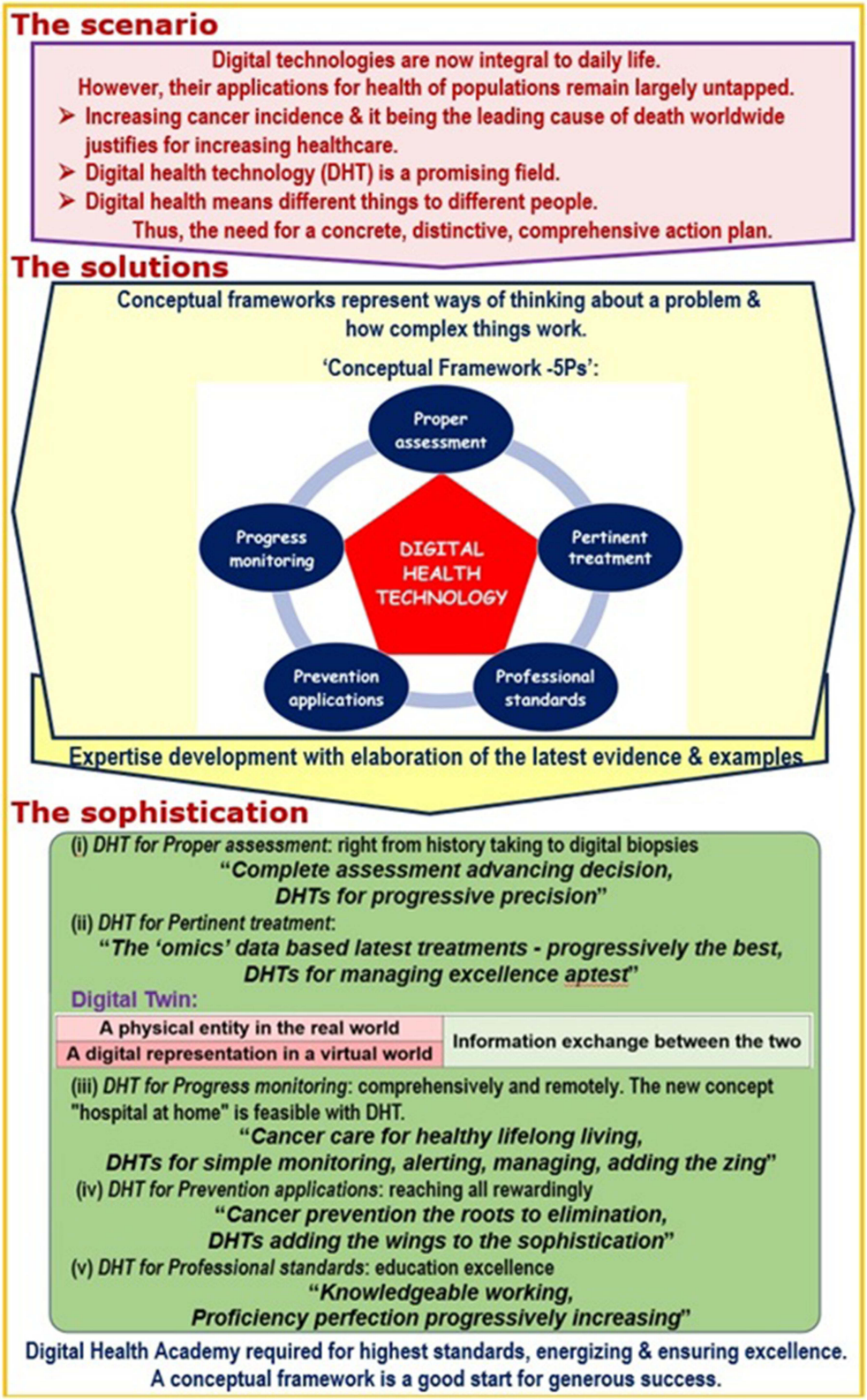
- DHT offers real opportunities to improve medical outcomes and enhance efficiency.
- Digital health means different things to different people. Thus, a need for a concrete, distinctive, and comprehensive action plan. We elaborate on the latest evidence with examples for the role of DHTs in practical applications as "Conceptual Framework – 5Ps" comprising:

(i) DHT for Proper assessment: right from history taking to digital biopsies.

(ii) DHT for Pertinent treatment: precision treatments.

Received: 9 July 2024
Accepted: 30 October 2024
Published: 8 December 2024

Graphical Abstract



Digital self-management interventions improve symptom outcomes in adult cancer patients. Digital health can help cancer patients gain more autonomy, self-acceptance, and personal growth.

(iii) DHT for Progress monitoring: comprehensively and remotely.

"Hospital at home" concept feasible with DHT.

(iv) DHT for Prevention applications: reaching all rewardingly.

(v) DHT for Professional standards: education excellence.

► DHTs can enable the delivery of advanced, high-quality care. We hope our work progresses mindsets, practices, and policies majorly.

Keywords: delivery of health care, computer simulation, digital innovation, technology, decision making, computer-assisted

Introduction

Digital technologies are now integral to daily life. However, its application to improve the health of populations remains largely untapped.[1] Cancer is common. Alleviation of suffering and cure needs approaches that are widely applicable.

The estimates of cancer incidence and mortality are alarming. These suggest that approximately one in five men or women develop cancer in a lifetime. Most distressing and alerting is that around one in nine men and one in 12 women die from it.[2]

Cancer incidence is increasing and is expected to be the leading cause of death in every country in the world.[3–5] Hence, there is a need for increasing healthcare, ranging from primary to tertiary levels. Delivery of care is important. Presently, even advanced countries like the United States grapple with growing disparities in cancer-related outcomes between their rural populations and urban and suburban counterparts.[6] Complementing doctors' intelligence with Artificial Intelligence to enhance patient care and augment clinical practice is a useful trend.[7] Digital health technology for improving access to care is a promising field with favourable potentials.

A recent scoping review has identified several notable gaps in digital health and telehealth in cancer care. This highlights only for remote cancer care, particularly for older adults and bereaved families. However, it suggests the need to integrate and sustain these interventions within oncology.[8]

Digital technology is revolutionizing health care, with enhanced delivery of quality care. Digital Health Technology (DHT) offers real opportunities to improve medical outcomes and enhance efficiency.[9] DHT uses computing platforms, connectivity, software, and sensors. Digital tools provide a more holistic view of patient health through access to data. Patients are empowered for their health.[9] These should definitely be used for cancer care.

The WHO and the International Atomic Energy Agency are collaborating to identify "best buys" and other cost-effective, priority strategies for cancer prevention and control.[3] Cost-effectiveness of any intervention is important. A recent systematic review has shown that there is a growing body of evidence that digital interventions have a generally favourable effect in terms of costs and health outcomes.[10] A professional approach to DHT in cancer care is likely to improve things further. A concrete conceptual framework can further catalyze all this, and with this aim we elaborate things for energetic excellence.

Current Evidence

We conducted a comprehensive electronic literature search to assess the current status for future directions. Only literature from the past seven years was included, as technology advances rapidly and older studies become obsolete. Guidelines from statutory medical institutions worldwide were analysed. The current evidence is presented, for progressing correct expertise, as a conceptual framework.

Conceptual Framework

Increasing efficiency and effectiveness requires a comprehensive framework. Conceptual frameworks represent ways of thinking about a problem and ways of representing how complex things work.[11,12] Our earlier work on advances in technology had pointed "Technology is permeating all aspects of health care, hence the need for a comprehensive multi-faceted

perspective and a model.[13] This should serve well for cancer care. We elaborate on the role of DHT as "Conceptual Framework" comprising five components (5Ps), illustrated in Figure 1. Patient care is inherently multimodal, requiring the interpretation and integration of insights between many data modalities spanning text, imaging, genomics, etc, simultaneously.[14] Implementation requires various DHTs. The applications of various subcategories of DHTs,[15] for the five components (5Ps), are illustrated in Figure 2.

The WHO "FRAMEWORK FOR ACTION" is an administrative writing, with four major components: commit, catalyse, measure, and enhance and iterate.[16] This envisages the creation, introduction, and scaling up of appropriate digital health technologies. It is important to reiterate here that healthcare is holistic, and each aspect should be delineated for exemplary dedicated actions. Professional working requires pinpointing actions pertinently. Our Conceptual Framework provides a concrete comprehensive action plan.

A recent publication has brought out progress and lacking progress aspects of digital cancer care.[17] The positive progress ones are (i) innovation in research and in care, (ii) digital pathology, (iii) digital radiology, (iii) real-world data,

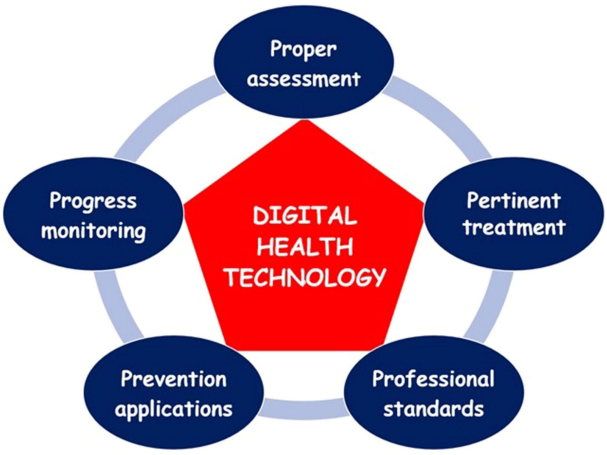


Figure 1 DHTs "Conceptual Framework" - 5Ps.

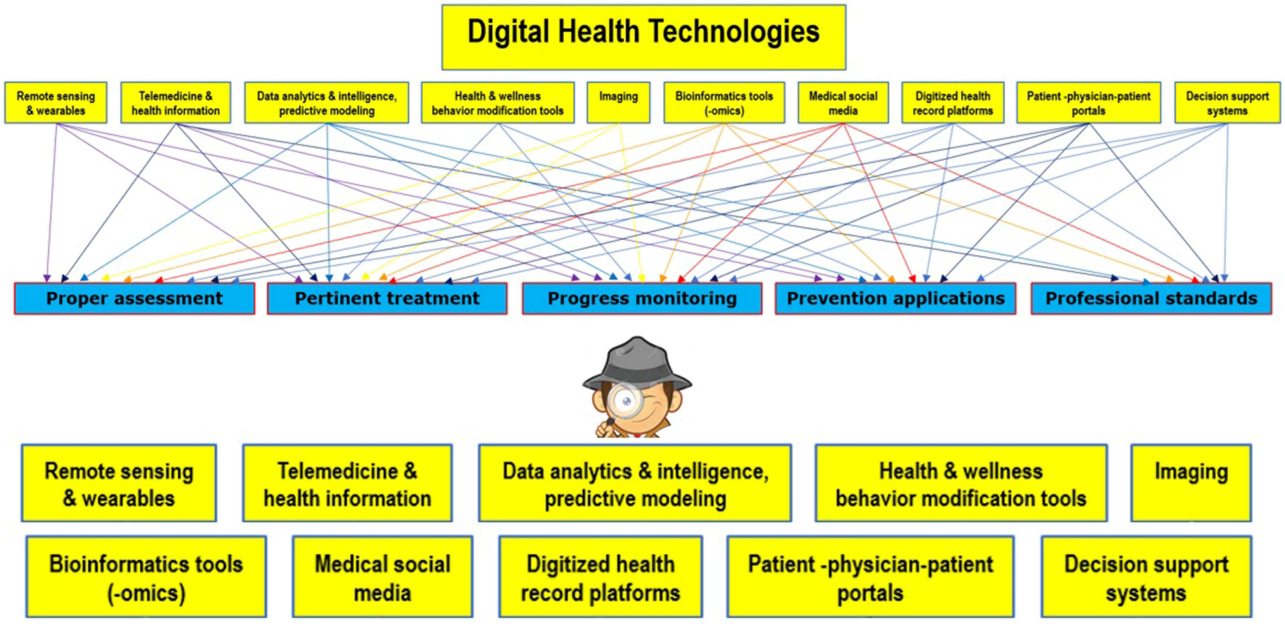


Figure 2 DHTs and their applications "5Ps".

(iv) next-generation sequencing, (v) patient-reported outcomes, and (vi) precision approaches driven by complex data and biomarkers. The lacking areas pointed are (i) remote patient monitoring, (ii) decentralized approaches to care and research, (iii) "hospital at home", and (iv) broad deployment of machine learning techniques to improve cancer care.[17] Again, it is important to address all these in a systematic, concrete, and simple framework, covering all aspects of healthcare from patient assessment to treatment, to monitoring, to prevention, and all this with professional standards, for patients and the public. Our "Conceptual Framework − 5Ps" is for energizing progressive excellence.

We elaborate on the current evidence, with examples for thoughtful implementation and future directions for DHT Cancer Care as per the proposed framework:

(i) DHT for Proper Assessment

DHTs are useful right from history taking to digital biopsies. Proper assessment involves (a) establishing the type of cancer (b) the extent of disease, and (c) the patient's fitness.

Routine history and physical examination details reveal important information. Recording these is of paramount importance, for current management and the future. Lawrence Weed, the inventor of the problem-oriented medical record, famously argued: the way physicians structure data affects how we think.[18] Thoughtfulness is definitely needed for tactful cancer treatment! DHTs (AI-driven applications) are available to capture the dictation of medical notes and should fulfil the true spirit of Weed, for success for the patient and sophistication for the future.[19]

Cancer diagnosis relies most heavily on invasive tissue biopsy, which is the gold standard. Digitalization of biopsy images has many advantages. This provides for real-time remote access to images, enhancing the reporting process by experts from anywhere. These will also form the basis of artificial intelligence and machine learning, for newer actionable insights.[20] "Pathomics" is a recent discipline enhancing diagnostic accuracy and usefully finding new predictive or prognostic factors.

Novel methods of quantitative image analyses (such as "radiomics" or "pathomics") have the potential to provide for prediction of underlying molecular drivers, tumor-immune microenvironment, tumor-related prognosis, and clinical outcome (in terms of response or toxicity) following immunotherapy.[21]

Assessment of tumor burden is important as it determines curability, inversely. Clinical, pathological, and surgical staging are all important. These are done initially and subsequently with treatment [Tumor, Node, and Metastasis staging system (TNM): clinical TNM (cTNM), pathologic TNM (pTNM), post-neoadjuvant therapy (ypT), staging at the time of retreatment for recurrence (rTNM) or autopsy staging (aTNM)]. Assessment of physiologic reserve of the patient is important, as it is a determinant of how patient is likely to cope with the physiologic stresses imposed by the cancer and its treatment. This is done using Karnofsky or Eastern Cooperative Oncology Group (ECOG) performance status. Further, a critical component of cancer management is assessing the response to treatment, eg Response Evaluation Criteria in Solid Tumors (RECIST). Digital records of these should improve management. Predictive analytics, based on machine learning, have recently been shown to provide more accurate predictions than clinical risk scores.[22] Digital records, diligence, and care delivery are desirable.

Screening is important and needs proper attention progressively. It has been shown to potentially reduce disease-specific deaths in cervical, colon, lung, and breast cancer. A systematic review has shown that mobile health (mHealth) technology interventions play a promising role in promoting cancer screening participation [overall pooled odds ratio 1.49 (95% CI 1.31–1.70), with similar effect sizes across cancer types]. The types of interventions included (i) peer support, (ii) education or awareness, (iii) reminders, and (iv) mixed.[23] Ease of mHealth technologies can be simultaneously leveraged for healthy lifestyle assessment and advancements.

"*Complete assessment for advancing decision,*

DHTs for progressive precision"

(ii) DHT for Pertinent Treatment

Practice with evidence-based guidelines, prevention of treatment adverse effects, smooth information flow between multi-disciplinary clinical team members, proactive engagement of patients in their own care, are all required in cancer

care continuum. Promising increases in all of these have been shown with DHTs, increasing healthcare quality and timeliness.[24]

Digital therapeutics is interesting, with easy collection and analyses of user-generated data. All this enables continuous monitoring and adjustment of interventions, leading to more precise and effective treatments.

Precision oncology holds the promise of reducing side effects and maintaining drug effectiveness. Digital twin is a computer modelling technique to develop treatments tailored to suit each person/child with cancer. A personalised computer model of each patient is used to simulate disease progression, predict outcomes if a drug is administered, and assess what happens if a drug does not work. By expertly utilising advances in mathematics, machine learning, and artificial intelligence, "virtual digital twins" are created. Cancer and disease treatments for each patient are tested first "in silico".[25,26] Representation of "Digital twin" working is given in Figure 3. The usefulness of Digital twins is the improvement of clinical protocols from mathematical models (MMs), precise treatments, prevention tact, oncologists training, and virtual clinical studies.

An Artificial Intelligence-based digital pathology approach is practical, with the added advantage of quantification of biomarkers automatic and intelligent from histopathology images. This makes it increasingly important for improving the selection of cancer treatments for patients.[27]

Radiotherapy is administered to more than half of all cancer patients. Radiotherapy forms part of the treatment in 40% of those cancer patients considered cured. Radiotherapy side-effects are a cause of concern. Any improvements to radiotherapy, even small improvements, will benefit a great many people.[28] A recent study has shown that mandatory supplemental evaluations for ML-identified high-risk patients are associated with both reduced total medical costs and improved clinical outcomes.[29] DHT can progress and make this expertise widely available.

Digital self-management interventions have been shown to improve symptom outcomes in adult cancer patients.[30] These, target on self-symptom relief. Digital health can help cancer patients gain more autonomy, self-acceptance, and personal growth.[31]

It has been suggested that digital technologies may be leveraged to provide psychosocial support for adolescent/young adults (AYAs) with advanced cancer.[32] Digital technologies are popular among AYA, and it is right time to use these for right purposes.

A systematic review of the effect of DHTs on managing symptoms across pediatric cancer continuum has shown a trend of positive effects with DHT interventions with interactive function.[33]

"*The 'omics' data based latest treatments which are progressively the best,*

DHTs for managing excellence apt & latest"

(iii) DHT for Progress Monitoring

Patient progress monitoring is multidisciplinary team (MDT) effort, and DHTs can definitely integrate and progress these. DHTs can make things interesting, comprehensive, and also possible remotely. The new concept "hospital at home" is feasible with DHT.[17]

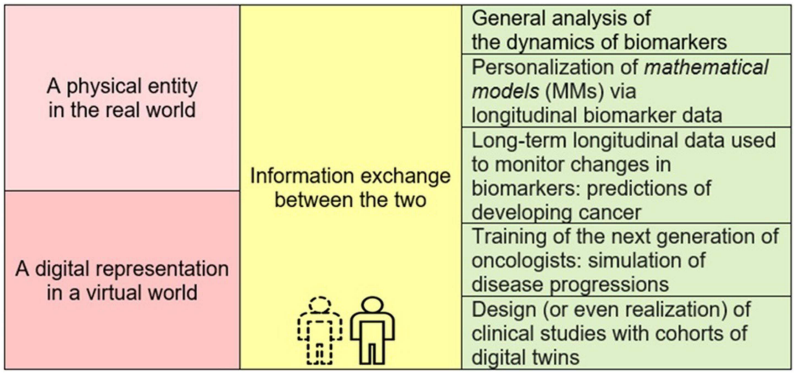


Figure 3 Digital Twin working.

Oncology Hospital at Home (HaH) programs have been proposed for quality oncology care, with the advantage of increasing patient satisfaction at a lower cost.[34] Real-world clinical utility and impact demonstration is important. Digital patient monitoring is being studied as ORIGAMA (MO42720), an interventional, open-label, multicountry platform study.[35] Remote Self-Reporting of Symptoms by Patients with Palliative Care Needs (RELIEF), a web-based application for symptom self-reporting by patients, has been shown to be a feasible and acceptable method.[36]

Patient-provider communication is a critical component of cancer care. A systematic review of digital interventions to improve patient-provider communication has shown evidence of preliminary efficacy.[37]

Digital stethoscopes can also be used for remote monitoring of cancer patients who are under isolation due to penetrating radiation, such as after the administration of Iodine-131. Instructions are provided on the placement of the stethoscope diaphragm, and doctors can listen to and analyse the patient's internal body sounds. DHTs advancements provide for advanced playback and speed-changing options.[38]

"*Cancer care for healthy lifelong living,*

DHTs for simple monitoring, alerting, managing, adding the zing"

(iv) DHT for Prevention Applications: reaching all rewardingly

Carcinogenesis is a process that usually extends over years, offering opportunities for prevention suitably and sustainably. The causal pathway of cancer involves biologic, environmental, social, and genetic factors.[39]

A number of infectious agents cause cancer. Notable are Hepatitis B and C linked to liver cancer; HPV strains linked to cervical, anal, and head and neck cancer; and Helicobacter pylori associated with gastric adenocarcinoma and gastric lymphoma. Vaccines importantly reduce the risk. DHTs, including social media, play an important role in tactful popularization and timely implementation. Also, anti-vaccine supporters attack digitally. Against these, excellent grassroots efforts are also digital. An excellent example is "Shots Heard Round the World" (www.shotsheard.com) led by two pediatricians in the United States.[40]

Early detection and progress prevention with risk factors attention is essential. Screening requires expert approaches. A prospective study has shown that machine-learning models enable the targeted identification of high-risk individuals, and achieve over 100-fold-greater efficiency.[41]

A Systematic Review and Meta-Analysis on Breast Cancer Detection at Screening Digital Mammography has found that standalone AI for screening digital mammography performed as well as or better than radiologists.[42] Routine repeated tasks can be done by DHTs, leaving room for personal care and progress for physicians.

A meta-analysis studied the effect of DHT interventions for promoting colorectal cancer (CRC) screening uptake. The DHT subtypes identified were decision-making aids and tailored educational interventions. Digital decision-making aids were found to significantly improve CRC screening uptake, compared to tailored digital educational interventions and usual care. Decision aids interventions facilitate patients' decision-making process by providing information on options with their benefits and harm, while considering their personal values and preferences. Portability and interactivity for the participant via web- or tablet-based delivery mediums is advantageous and should be advanced suitably.[43]

"*Cancer prevention the roots to elimination,*

DHTs adding the wings to the sophistication"

DHT for Professional Standards: education excellence, and advanced information accessible

All cancers are driven by genetic changes, hence important to understand the principles of genomics.[44] All this is easily possible with technology. Technology proficiency will make these efficient.[13] Thorough understanding of DHT applications sophistication is required to maintain standards.

Proficiency

Proficiency is desirable when using DHTs fast-advancing favourable applications. Doctors may not have the information they need to use a given DHT.[15] General Medical Council, UK, and Medical Council India have been proactive in technology training.[13] Curriculum Development for diligent and comprehensive "Technology Proficiency" has been proposed, based on the six-step approach to curriculum development proposed by Kern et al.[13,45]

Healthcare professionals should explore and learn in areas such as engineering or computer science, and equally, graduates in these areas should consider doing the same in healthcare. All this will lead to technological solutions creation best and impactful, and correct befitting implementation. Healthcare professionals' critical appraisal skills are essential to determine which patients DHT should or should not be used for, and to assess the accuracy of the software.[22]

The gift of time is a key benefit of DHTs for doctors, freeing them to focus on providing their best comprehensive clinical care, while also saving time on clerical tasks and commuting. As a result, overall highest professional standards should be achieved.

"*Knowledgeable working,*

Proficiency perfection progressively increasing"

Regulations & Ethics Rigour

All new technologies must meet the same bar for clinical evidence as other clinical interventions.[46] Clinical validation of DHTs is a must. Clinical trials are essential. Confidentiality, security, and data privacy issues are significant and need to be suitably addressed. DHT applications are rightly and stringently regulated in the US.[9,47] A WHO report states that less than 50% countries had legislative requirements to formalize health technology assessment (HTA) results in healthcare decision-making in 2015.[48] Results of an update to this survey conducted in 2020–21 are awaited.[49] "The Topol Review", an important report, recommends "increase the number of specialists in the evaluation and regulation of digital technologies".[22] This can improve things worldwide. Government guidance is remarkable for its breadth, detail, and timeliness.[50]

Importantly, the bottom line is:

"*Regulation is perceived as a barrier to innovation, however,*

Seriously & significantly, regulation is best boost to sound & safe innovation, &

Without regulation it is just innovation!"

Digital Health Academy: distinctive cancer care

A top guiding, regulatory, and governing academy in each country is the need of the hour. It has been suggested that governments should invest for developing specialist digital skills of the workforce, for the assessment and commissioning of digital technologies.[22] Digital Health Academy [DHA] should be a good start.

New interventions and technologies are constantly being developed and refined.[13] Cancer care is critical and most professional. Establishing an academy becomes important for DHTs' robust advancements for right applications. Academic excellence ensures Evidence-Based Medicine applications.

DHA should be brought up as a "Center of Excellence" (CoE). CoE has the ability to dramatically enhance the depth and breadth of healthcare services. Successful development of a CoE first requires the acquisition of a detailed understanding of the delivery model and its benefits.[51] A recent scoping review on CoE has concluded with the need for a comprehensive framework to guide and inspire an institution as CoE.[52] The "5Ps" Conceptual Framework proposed by us suits the establishment of and excellence in functioning methodically.

A global synthesis of the evidence to conceptualise CoEs has identified 12 essential foundations of CoEs. Six of these focus on administrative aspects, and another six on professional aspects.[52] We specify the professional functioning for DHA as 6Ss, at Figure 4.[53]

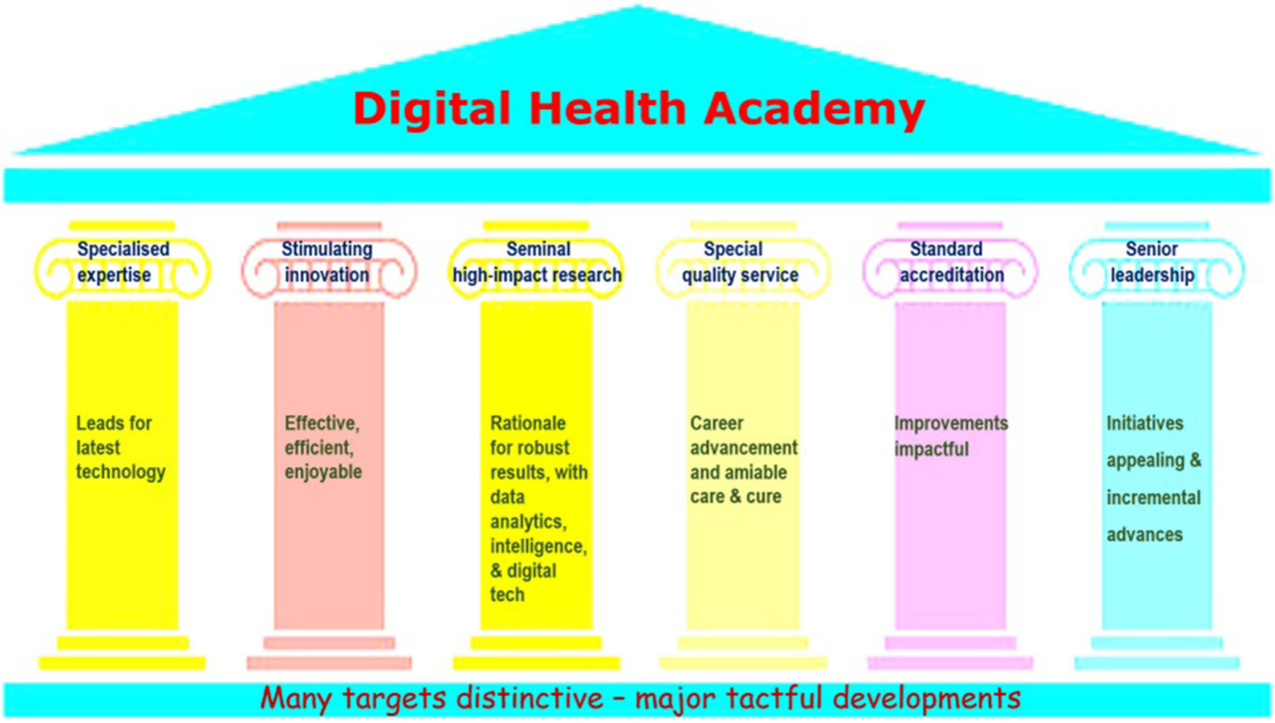


Figure 4 DHA: foundations for future favourable.

"*Efforts & expertise excellence,*

Ensured & energised with Digital Health Academy, the precedence"

Conclusion

Digital interventions make cancer care convenient, transcending time and physical boundaries.

In the present state of healthcare and growing demands, good developments in DHT seem to be the answer. A conceptual framework is a good start for generous success for all. Its "5Ps" components provide for focused and favourable progressive innovations and interesting practical applications advancements. We hope our work progresses mindsets, practices, and policies majorly.

"*Increasing Cancer care peculiarities,*

Interesting digital technologies, the pertinent practice amenities,

Ever increasing cancer 'omics' data complexities,

Data driven digital technologies for simple success realities,

'5Ps' conceptual framework for progressing comprehensive highest care qualities"

Acknowledgments

(i) This paper was presented in the 8th World Cancer Congress 2024 https://worldcancercongress.in/wcc2024.php.
(ii) The authors convey special thanks to all authors of the references quoted.

Disclosure

The authors report no conflicts of interest in this work.

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