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INNOVATION REPORT

Using large-scale dataset to identify opportunity for implementing technology-based intervention to improve cancer care in India

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Table of Contents

List of Figures

List of Tables

Acronyms

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Declaration

This report is submitted to the University of Warwick in support of my application for the degree of Doctorate in Engineering. It has been composed by myself and has not been submitted in any previous application for any degree.

Parts of this thesis have been published/ presented at international forums by the author.

Publications

1. Ramachandran V, Pradhan A, Kumar A, Sarvepalli BK, Rao S, Oswal K, Kommu RS, Sharma M, Pathak S, Kunnambath R, Kuriakose MA, Rengaswamy S, Alajlani M, Arvanitis TN. A Distributed Cancer Care Model with a Technology-Driven Hub-and-Spoke and further Spoke Hierarchy: Findings from a Pilot Implementation Programme in Kerala, India. Asian Pac J Cancer Prev. 2022 Sep 1;23(9):3133-3139.
   Availble at: doi: 10.31557/APJCP.2022.23.9.3133.

2. Ramachandran V, Pradhan A, Kumar A, Purushotham A, Alajlani M and Arvanitis TN (2022) Digital Inequalities in Cancer Care Delivery in India: An Overview of the Current Landscape and Recommendations for Large-Scale Adoption. Front. Digit. Health 4:916342.
   Availble at: doi: 10.3389/fdgth.2022.916342

3. Ramachandran V, Kumar A, Mantena S, Subramanian SV. Geographical variation in mobile phone ownership and SMS literacy among women (age 15–49) in India: A cross-sectional analysis based on National Family Health Survey-4, Technology in Society, Volume 64, 2021, 101482 , ISSN 0160-791X.
   Availble at: https://doi.org/10.1016/j.techsoc.2020.101482

4. Ramachandran V, Subramanian SV, Alajlani M, Arvanitis TN. Effect of mobile health interventions in increasing utilization of Maternal and Child Health care services in developing countries: A scoping review. Digital Health. 2022;8. doi:10.1177/20552076221143236

Associated publications

5. Sirohi, Bhawna et al. Developing institutions for cancer care in low-income and middle-income countries: from cancer units to comprehensive cancer centres The Lancet Oncology,2018, Volume 19, Issue 8, e395 - e406.
Availble at:
https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(18)30342-5/

1. Introduction

1.1. The need for this project

Cancer incidence in India is increasing, owing to a mix of risk factors such as changes in diet and lifestyle, high tobacco consumption rates and an aging and population with cancer being more common in older populations. In India, the crude cancer incidence rate increased by 28·2% from 63·4 per 100,000 in 1990 to 81·2 per 100,000 in 2016. Kerala and Mizoram had the highest rate of crude cancer incidence (figure 1) (Lancet Oncol, 2020).

The age-standardised incidence rate of breast cancer in females from 1990 to 2016 increased by 39·1%, with increase observed in every state of the country. The age-standardised incidence rate of cervical cancer decreased by 39·7% in India from 1990 to 2016 (Lancet Oncol, 2020). The trends observed in the top seven cancer type-specific incidence rates in India is shown in figure 2.

As per the latest National Cancer Registry Programme Report (2020) by the Indian Council of Medical Research (ICMR) - National Centre for Disease Informatics and Research (NCDIR) the number of cancer cases in India in 2020 was 1.39 million (100.7 per 100,000 population) (Mathur, 2020).

Lung, oral cavity, stomach, and colorectal cancers are the most common cancers in men. Cancer of the breast and cervix uteri are the most common cancers in women. Lung cancer is the leading site in metropolitan cities and the southern region, whereas mouth cancer was the leading site in the West and Central regions. The highest burden of breast cancer is observed in metropolitan cities (Naik, 2021).

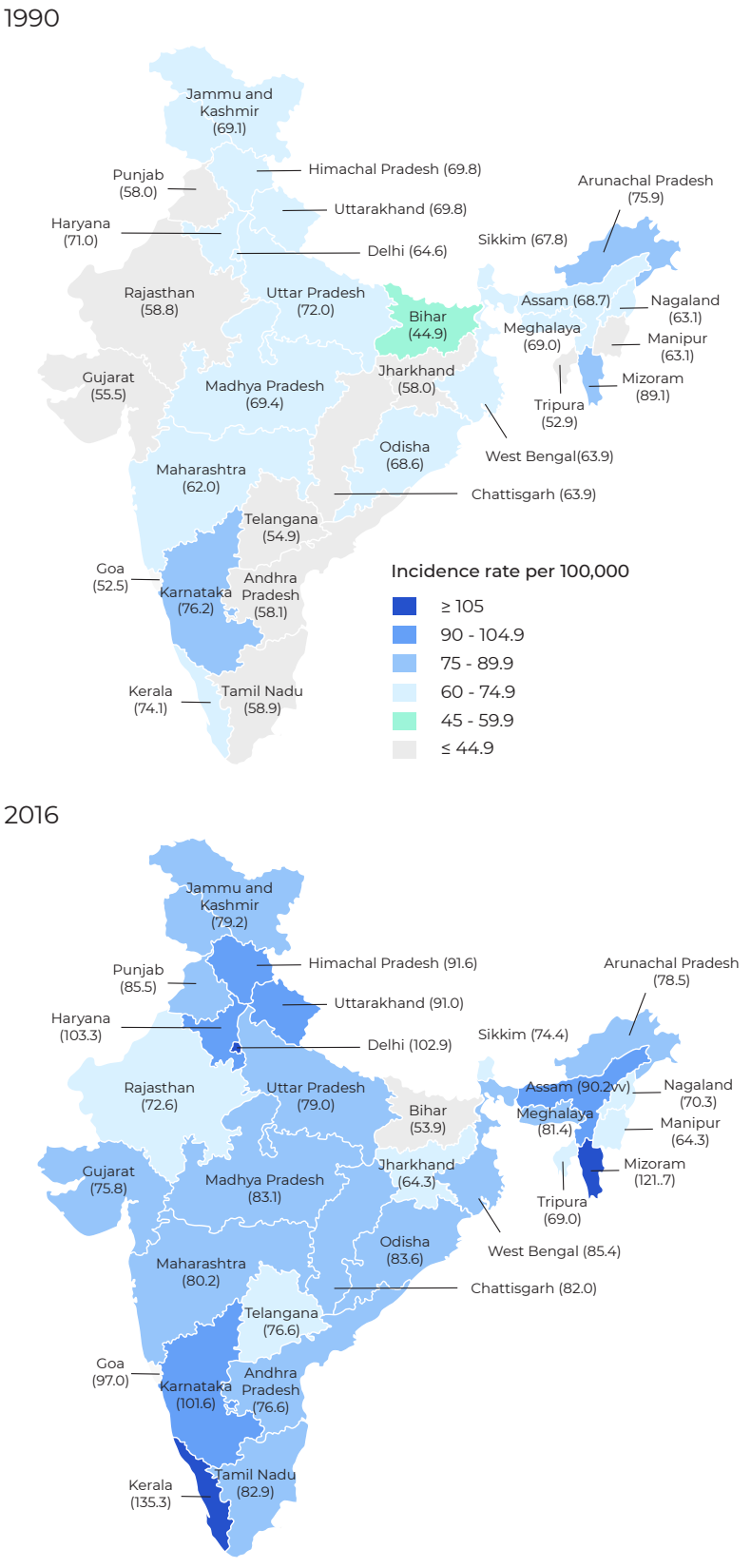
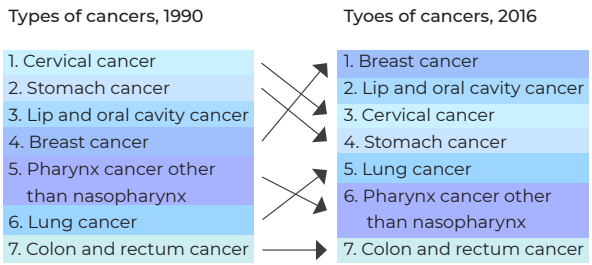


Figure 1: Crude annual incidence rate of all cancers together

Source: India State-Level Disease Burden Initiative Cancer Collaborators. The burden of cancers and their variations across the states of India: the Global Burden of Disease Study 1990–2016. Lancet Oncol 2018; 19: 1289–306



Mean percentage change in number of new cases, 1990-2016 (95% UI)	Mean percentage change in crude incidence rate, 1990-2016 (95% UI)	Mean percentage change inage-standardised incidence rate (95% UI)
188.3% (116.7 to 287.0)	89.2% (42.3 to 154.0)	40.7% (7.0 to 85.6)
95.9% (70.2 to 108.4)	28.5% (11.7 to 36.8)	-6.4% (-18.6 to -0.4)
19.7% (-14.8 to 47.2)	-21.4% (-44.1 to -3.4)	-39.7% (-57.3 to -26.5)
23.7% (15.1 to 35.6)	-18.8% (-24.4 to -11.0)	-39.7% (-44.0 to -34.3)
116.0% (89.1 to 132.1)	41.8% (24.1 to 52.4)	2.2% (-10.4 to 9.6)
104.8% (60.5 to 133.2)	34.4% (5.3 to 53.1)	-2.7% (-23.6 to 10.8)
128.6% (82.6 to 153.7)	50.0% (19.9 to 66.5)	10.3% (-11.4 to 23.2)

Figure 2: Change in incidence rate of the top seven cancers in India, 1990 – 2016

Source : Mathur, P et al. "Cancer Statistics, 2020: Report From National Cancer Registry Programme", India, JCO Global Oncology, 6, 2020, pp. 1063-1075.

Within India, the incidence of cancer varies dramatically based on the geographical location (north/south/northeast, rural/urban, and Ganges belt/Deccan plains). The highest rate of incidence of cancer is observed in the North-East (NE) region.

The trend for crude cancer disability-adjusted life-years (DALY) rate in India shows an increase by 25·3% from 1990 to 2016. Among females, breast, cervical, and stomach cancer were responsible for the highest DALYs in 2016. The highest cancer DALYs among males in India in 2016 were due to lung cancer, followed by lip and oral cavity cancer, other pharynx cancer, and stomach cancer. (Lancet Oncol, 2020) The DALY due to different types of cancer in 2016 is provided in figure 3.

As the country suffers from a lack of adequate healthcare infrastructure, there is a wider dearth of awareness on cancers and a severe scarcity of skilled human resources for cancer, hence, conventional healthcare delivery methods involving interpersonal doctor–patient interactions might not be available to most of the people in India (Golechha, 2015).

Despite the introduction of government-funded schemes and cancer care facilities at the medical colleges, for the average patient with cancer in India, health care remains highly privatised, with more than 80% of outpatient care and 40% of inpatient care provided by the private sector (Thakur et al,

2011). Consequently, expenditures on private health, especially on drugs, remain very high, exacerbating health inequalities.

Both sexes combined

Types of cancers*	% of total cancer DALYs
1. Stomach cancer	9.0%
2. Breast cancer	8.2%
3. Lung cancer	7.5%
4. Lip and oral cavity cancer	7.2%
5. Pharynx cancer other than nasopharynx6. Lung cancer	6.8%
6. Colon and rectum cancer	5.8%
7. Leukaemia	5.2%
8. Cervical cancer	5.2%
9. Oesophageal cancer	4.3%
10. Brain and nervous system	3.5%
11. Liver cancer	3.5%
12. Non-Hodgkin lymphoma	3.2%
13. Gallbladder and biliary tract cancer	3.1%
14. Larynx cancer	3.0%
15. Pancreatic cancer	2.4%
16. Ovarian cancer	2.2%
17. Prostate cancer	1.5%
18. Bladder cancer	1.1%
19. Nasopharynx cancer	1.0%
20. Thyroid cancer	1.0%
21. Multiple myeloma	1.0%
22. Hodgkin's lymphoma	0.9%
23. Uterine cancer	0.8%
24. Kidney cancer	0.7%
25. Mesothelioma	0.3%
26. Malignant skin melanoma	0.3%
27. Testicular cancer	0.2%
28. Non-melanoma skin cancer	0.2%

Females

Types of cancers*	% of total cancer DALYs
1. Breast cancer	16.8%
2. Cervical cancer	10.8%
3. Stomach cancer	9.0%
4. Colon and rectum cancer	6.1%
5. Lip and oral cavity cancer	4.6%
6. Ovarian cancer	4.6%
7. Lung cancer	4.4%
8. Leukaemia	4.3%
9. Gallbladder and biliary tract cancer	4.3%
10. Pharynx cancer other than nasopharynx6. Lung cancer	4.3%
11. Oesophageal cancer	3.5%
12. Brain and nervous system	2.9%
13. Non-Hodgkin lymphoma	2.6%
14. Liver cancer	2.3%
15. Pancreatic cancer	2.2%
16. Uterine cancer	1.7%
17. Thyroid cancer	1.3%
18. Larynx cancer	1.1%
19. Multiple myeloma	1.0%
20. Nasopharynx cancer	0.7%
21. Hodgkin's lymphoma	0.8%
22. Bladder cancer	0.6%
23. Kidney cancer	0.6%
24. Malignant skin melanoma	0.4%
25. Mesothelioma	0.2%
26. Non-melanoma skin cancer	0.2%
	0.1%

Males

Types of cancers*	% of total cancer DALYs
1. Lung cancer	10.4%
2. Lip and oral cavity cancer	9.6%
3. Pharynx cancer other than nasopharynx	9.1%
4. Stomach cancer	9.0%
5. Leukaemia	6.0%
6. Colon and rectum cancer	5.6%
7. Oesophageal cancer	5.1%
8. Larynx cancer	4.8%
9. Liver cancer	4.6%
10. Brain and nervous system	4.0%
11. Non-Hodgkin lymphoma	3.7%
12. Prostate cancer	2.9%
13. Pancreatic cancer	2.6%
14. Gallbladder and biliary tract cancer	2.1%
15. Bladder cancer	1.5%
16. Nasopharynx cancer	1.4%
17. Hodgkin's lymphoma	1.2%
18. Multiple myeloma	1.0%
19. Kidney cancer	0.9%
20. Thyroid cancer	0.7%
21. Testicular cancer	0.5%
22. Mesothelioma	0.4%
23. Breast cancer	0.3%
24. Non-melanoma skin cancer	0.3%
25. Malignant skin melanoma	0.3%

Figure 3: Percentage of total cancer DALYs due to different types of cancers by sex in India, 2016

Source : India State-Level Disease Burden Initiative Cancer Collaborators. The burden of cancers and their variations across the states of India: the Global Burden of Disease Study 1990–2016. Lancet Oncol 2018; 19: 1289–306

While there are debilitating challenges in the current state of cancer control in the country, the problems may further exacerbate in the future with an increase in the disease burden due to intensification of risk factors and ageing of the Indian population.

My years of experience has helped me to clearly understand that building more hospitals may not be the only solution to this problem. Many cancer centres that have come up over the past decade are mostly working in siloes, most of whom are catering to the treatment side of cancer – when the patients are already at advanced, metastatic stage. The solution to most of the cancers is in prevention and early detection of the disease by life-

modification, early diagnosis and standardized protocols. The delivery of this must be through an inclusive, participatory and partnership network – at the back of robust technology framework – encompassing both the private and public healthcare settings.

Karkinos Healthcare has been setup to democratise cancer care through an end-to-end technology driven oncology focused managed healthcare platform where almost no person is deprived of care either by lack of access or affordability.

The global big data in healthcare market size was valued at USD 32.9 billion in 2021 and is predicted to reach USD 105.73 billion by 2030, increasing at a CAGR of 13.85% from 2022 to 2030 (Straits Research, 2022).

The focus really is on early detection - an affordable early detection and wellness with assured navigation and comprehensive support in event of an illness. The early detection services have huge potential and is largely unexplored. Despite the availability of screening tests for free, most cancers are detected in late stages of the disease. In India, the number of people eligible for early detection within the age group of 30 to 65 years are 37% of Indian population (~480 million).

There is a growing need for interventions in India for making cancer care more affordable, acceptable, accessible and standardised to a wider population, so as to reduce the problems of late detection, quality of care and lost to follow-up, leading to the high mortality rates.

1.2. Research objectives

There are huge challenges faced by the health system of India. Accessibility, availability, affordability, quality of services and insurance are some of the major issues. Healthcare providers and health centers are disproportionately distributed. While the public health centers attempt to address the accessibility issue, it suffers low utilisation due to lack of trained human resources and quality care. The private health systems are clustered in towns and cities, and people who are willing to travel the long distance,

primary healthcare services at the private centers come at a cost, which majority of the population are unable to afford. These factors lead to poor health outcomes and affect health and wellness of marginalised population in the country.

Technology as an enabling mechanism to transit to an efficient and effective healthcare delivery system in India will be explored in this study. While the research will focus on penetration of technology in Indian household and usage of digital solutions for healthcare services, key determinants of technology penetration and usage shall be discussed. The research shall largely focus on understanding access or lack of access to cancer care services and explore the use of technology-driven solutions to improve outcomes. The following are the research objectives -

1.2.1. Objective 1

The extent of digital penetration in Indian households and the distribution of mobile technology across gender, various population groups and geographic units in India to access the utilization of public health services.

1.2.2. Objective 2

To review studies on development and management of cancer centres in high-income and low-middle-income countries and assess the digitisation of cancer care services in India against the context of global technological advancement.

1.2.3. Objective 3

To develop a technology framework and managed delivery platform for implementing purpose-driven oncology program in the state of Kerala in India.

The study aims to develop a technology-driven mechanism to support implementation of a distributed model of cancer care delivery system in low

resource settings to improve the outcomes by tacking the challenges of lack of accessible and quality cancer care services.

1.3. Structure of this report and EngD portfolio

The structure of the report is divided into five parts to make single portfolio, each consisting of one or multiple submissions. A diagrammatic representation of the portfolio structure is provided in figure 4.

1.3.1. Problem Identification

Submission 1: Problem Statement

The submission describes the current lack of health awareness, accessibility and affordability in the public health system of India leading to its low utilisation and contributing to poor health outcomes. The problem statement highlights the prevailing inequalities in healthcare delivery, and particularly in cancer care, between and within states, and between urban and rural areas, in India.

The stark divide in technology usage among the developed and the developing countries for availing healthcare services is stressed. The problems of late detection, quality of care and lost to follow-up in cancer patients, leading to significant mortality rates is reiterated, and the need to develop a wider strategy to tackle the burden in a resources constraint setting is laid down.

1.2.1. Problem Investigation

Submission 2: Systematic Review on Effect of mhealth Interventions in Increasing Utilization of Maternal and Child Health Care Services in Less Developed Countries

The paper reviews the experience of developing countries about the effectiveness of mhealth interventions and barriers to mobile-based health interventions.

1. Problem Identification

Submission 1: Low utilization of health care services

2. Problem Investigation

Submission 2: Review of mHealth interventions

Submission 3: Data and Methodology

Submission 4a: Geographic distribution of mobile phones among women
Objective: To investigate the contribution of different geographic levels towards variation in mobile ownership and SMS literacy among women

Submission 4b: Socio-economic inequalities in distribution of mobile phones among women
Objective: To investigate the association between mobile ownership and SMS literacy among women and their socio-economic characteristics

Submission 4c: Review to explore factors that influence the development of a cancer center
Objective: To review studies on development and management of cancer centres in low-income and middle-income countries

Submission 4d: Digital inequalities in cancer care delivery in India
Objective: To review the current gaps and explore possible solutions in digitisation of cancer care services in India against the context of global technological advancement

3. Developing the Solution

Submission 5a: Emerging Hub-And-Spoke Models of Technology-Enabled Cancer Care: A Systematic Review

Submission 5b: Designing a Purpose Driven, Technology-Enabled Hub-and-Spoke Cancer Care Model using the Business Model Canvas

4. Testing and Implementation

Submission 6: Healthcare Technology Platform Framework for Purpose-Driven Oncology

Submission 7: Implementation of a Technology Enabled Distributed Cancer Care Model in Kerala

5. State of Innovation and Personal Development

Submission 8: Statement of Innovation: Use of large-scale dataset to identify opportunity for implementing technology-based intervention

Submission 9: Personal Development

Figure 4: Portfolio Structure

A review of literature was conducted based on papers published between 1990 and 2021. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. PubMed and Cochrane Review were used to identify the studies. The studies were shortlisted on the basis of title and abstract which were retrieved on the basis of certain key words. The aim was to identify the studies for developing countries which evaluated the success of mhealth interventions in increasing the utilization of maternal and child health services (particularly immunization) and barriers which prevented the use among both health care workers as well as beneficiaries. The research was considered to be rigorous if the method to evaluate the health intervention involved randomized control trials.

A total of 573 studies were located using PubMed and Cochrane Review. After removing duplicates 141 remained. Finally, a total of 28 studies were selected for review. 16 of the studies were review papers and based on RCT.

The study shows that experience of other developing countries with respect to mhealth interventions has been positive. The findings suggests that mhealth interventions can improve access to maternal health services, and that incentive linked compliance through text messaging can lead to higher immunization coverage. Clearly, such interventions can be instrumental in reducing maternal and child mortality

Submission 3: Data Collection and Methodology

Data Collection and Methodology for the problem investigation section of the portfolio is provided here. The submission details the research topics and data-sets to be explored to understand the following: (a) the accessibility and availability issues around health in remote corners of India, (b) the nature and pattern of digital penetration and (c) the potential of technology to improve health outcomes, particularly in cancer care. The following research questions were identified for the problem investigation -

1. What is the extent of digital penetration in Indian households and the distribution of mobile technology across various population groups and geographic units in India?

2. What is the role that gender plays across both of these dimensions of technology and healthcare access, and do we find serious gaps in access faced by women?
3. What is the extent of development and management of cancer centres in low-income and middle-income countries? How professionalized is the development in the context of an emerging of global attention on all aspects of health- system strengthening?
4. What are the current gaps in digitisation of cancer care services in India? What are the emerging solutions aiming to bridge this gap?

Submission 4a to 4d explores the research questions in detail using various available data sets and published research works of population in India and outside.

Submission 4a: Geographical variation in mobile phone ownership and SMS literacy among women (age 15–49) in India: A cross-sectional analysis based on National Family Health Survey-4

The submission explores the extent of digital penetration in Indian households and the distribution of mobile technology across various population groups and geographic units in India. There are no studies with a large sample size that present the variation in mobile phone ownership and ability to read short message services (SMS) message among women across different geographic levels.

Multilevel models are used to estimate the contribution of geographic levels in explaining the variation in mobile phone ownership and SMS literacy. The data from the fourth round of National Family Health Survey (NFHS) which collected information on health and nutrition indicators was used for our analysis. 122,351 women were interviewed about mobile phone ownership and SMS literacy. Information on mobile phone ownership and ability to read text messages were used to create the dependent variables. The independent variables included women's education, age, religion, social class, wealth quintile and place of residence. Two and four level variants of a

multilevel model, with individuals (level-1) nested within primary sampling unit (level 2), districts (level 3) and States (level 4), were used to estimate the probability of mobile phone ownership and ability to read text message.

The findings suggest that understanding the magnitude of inequalities at different geographic levels should be warranted more attention before tackling the socio-economic factors. State estimates should be supplemented with information available for lower geographic levels. It is important to identify the geographical clusters with high and low coverage of mobile ownership and ability to read text messages before implementing mhealth interventions.

Submission 4b: Socioeconomic inequalities in mobile phone ownership and digital literacy among women (Age 15-49) in India: An econometric analysis based on NFHS-4

The submission highlights the socioeconomic inequalities in mobile phone ownership and digital literacy among women (Age 15-49) in India using an econometric analysis based on NFHS-4.

In India, mobile phones have emerged as a cost-effective tool to overcome the digital divide and to promote economic growth. However, mobile phone ownership is lower among women in India. Women who lack mobile phones and are digitally illiterate will be left out of the knowledge society and will not have a level playing field. Using nationally representative household survey data, we investigate the association between mobile ownership and SMS literacy among women with their demographic and socio-economic characteristics.

The analysis is based on the fourth round of the National Family Health Survey (2015-16) of 122,351 women (age 15-49 years). The data, obtained using a long interview based questionnaire, provide information on maternal and child health indicators. Women have a mobile phone and can read text messages were the dependent variables. The independent variables included women's education, age, religion, household's social class, wealth quintile and place of residence. Absolute and relative inequalities in mobile

ownership and SMS literacy across socio-economic groups have been computed. Multilevel models were calibrated, conditional on the random effects at the level of State, districts and PSUs, to assess the associations.

Education and wealth status of the women have strong association with mobile ownership and SMS literacy. The probability of owning a mobile and SMS literacy is higher for women who have completed more than secondary education and belong to higher wealth quintiles. Inequalities based on education are particularly stark for SMS literacy. Further, inequalities are present across groups of religion, caste, place of residence and age of women. The associations are validated using multilevel model.

The magnitude of relative inequalities within wealth and education groups indicates that those on a lower socio-economic plane are at a greater disadvantage. Sustained policy efforts are required to make women a part of the knowledge society. Focus on improving educational outcomes and income is the key to increase the adoption of mobile phones and improve digital literacy among women.

Submission 4c: Developing institutions for cancer care in low-income and middle-income countries: from cancer units to comprehensive cancer centres

The submission explores the essential aspects of the creation, organisation, accreditation, and activities of cancer centres in a wide range of sizes, scales, and ecosystems across the world. This analysis explores cancer from a structural and organisational perspective, focusing on the professionalisation of cancer centres as part of the emergence of global attention on all aspects of health- system strengthening.

We searched MEDLINE; Web of Science; Library, Information Science and Technology Abstracts; and PubMed using the subject heading and abstract terms, “India”, “Latin America”, “Africa”, “Middle-East”, “China”, “Low and middle income countries”, “comprehensive cancer centre”, “cancer centre”, “healthcare”. Articles published between Jan 1, 1980, and Dec 31, 2017, were included. We also reviewed resource stratified guidelines and *Lancet*

commissions that dealt with cancer care delivery and provision in low-income and middle- income countries.

The analysis of both HICs and LMICs shows that substantial challenges need to be addressed, including ensuring equitability between private and public cancer centres, distributional barriers due to extreme geography or lower development, the scarcity of trained health-care professionals, and distributional inequality due to the coalescing of cancer centres in the same, often urban, areas.

The analysis summarises what has been published about the development and management of cancer centres in low-income and middle-income countries so far and highlight the need for clinical and political leadership.

Submission 4d: Digital Inequalities in Cancer Care Delivery in India

This submission evaluates the challenges in the adoption of digital technologies to deliver cancer care services and the provides recommendation for large-scale adoption in the Indian healthcare context.

Global health has improved significantly due to digitization, from early and more accurate diagnosis to increasing access to specialized care, capturing essential information at the point of care for better public health interventions, information delivering personalized care through mHealth, and managing healthcare services in community settings. Investing in digital health in resource-constrained countries can reduce direct care costs, enhance the access to health services, and improve health outcomes. There is a critical knowledge gap about patient-cantered applications of digital health technologies for cancer care in India. The needs of service providers in India are unique, and technological acceptance and integration can be achieved if the technological offerings are easy to use, less sophisticated, the benefits understood, cost-effective and secured. We analyse various socio-ecological challenges - from individual to community, provider and systematic level - for digital adoption of cancer care service.

Developments in digital infrastructure offer an unprecedented opportunity to overcome the conventional barriers of geography, infrastructure, and culture. Digital health has transformed the traditional healthcare system, where empowered patients can take informed decisions, customized to their needs. The increasing mobile phone penetration in India, particularly smart phone penetration, provides unprecedented opportunities for m-health in India. Adopting digital solutions across the care pathway of prevention, diagnosis and cure can transform the delivery of cancer care services, yielding improved outcomes.

For equitable digital healthcare, the need is to have a participatory approach of all stakeholders and urgently addressing the digital divide adequately. Sharing of health data of public and private hospitals within the framework of the Indian regulations and Data Protection Act is critical to development of digital health in India and it can go a long way in better forecasting and managing cancer burden.

1.2.2. Developing the Solution

Submission 5a: Emerging Hub-and-Spoke Models of Technology-Enabled Cancer Care: A Systematic Review

The submission studies peer-reviewed articles to understand the emerging hub-and-spoke models of distributed cancer care across the world with technology as the backbone. Using the PRISMA guidelines, country-specific articles as well as articles which reviewed hub-and-spoke models across other High Income Countries (HICs) and Lower Middle Income Countries (LMICs) were identified.

All the studies identified were conducted between 2010 to 2020. We used 16 keywords to identify research articles. The search strategy was a combination of keywords including ‘emerging’ or ‘new’ and ‘technology’ and ‘hub-and-spoke’ or ‘distributed’ and ‘cancer’. After understanding the types of articles that would result from the search terms, additional terms were added to narrow the scope of the literature findings. For our literature search we used the PubMed database and Google Scholar.

We collected 285 articles from our literature search. Once the duplicates were removed, we had 270 articles for further review. For the review process, we used an Excel workbook populated with general article information, title and abstracts. After completion of the abstract review, 238 articles were excluded due to being irrelevant.

Out of the 32 articles for full-text review, 6 were excluded due to non-availability of full-text articles. 15 full-text articles were excluded due to being irrelevant. We identified 11 articles of interest. Most of the studies identified were conducted for Lower Middle Income Countries (LMICs). Two studies were for India, four for the USA, two for Australia, one for England, one for Kenya,and the remaining three for the global population. All the studies addressed the need for equitable distribution of cancer services by elaborating their model of cancer care delivery, while also isolating the strengths and challenges.

Our analysis of both HICs and LMICs show hub-and-spoke models in cancer care as an emerging area, especially in the LMICs. Among LMICs, India is a leading example, with emerging hub-and-spoke models involving government infrastructure through public private partnerships, as well as through strengthening of the government's own public health system to deliver cancer care services even in low resourced settings.

It is clear from our findings that hub-and-spoke models improve cancer care across the patient’s journey, by virtue of making cancer services more accessible, affordable, coordinated and ensuring fair distribution of cancer services, ultimately improving cancer outcomes. HICs have widely delivered cancer care services and conducted research using the hub-and-spoke approaches, involving genetics as well, through a mix of technological models. As hub-and-spoke models are emerging in India, it needs to take into account the learnings and mistakes made by HICs. Crucially, this development should align with the political and cancer centre leadership, the cultural and socio-economic factors, and be within the context of

national policy for health systems, health human resources, and infrastructure.

Submission 5b: Designing a Purpose Driven, Technology-Enabled Hub-and-Spoke Cancer Care Model using the Business Model Canvas

The submission describes a purpose driven, technology-enabled hub-and-spoke model of cancer care in India using the Business Model Canvas (BMC). The BMC captures the essence of a building an end-to-end technology driven oncology focused managed healthcare Platform where almost no person is deprived of care either by lack of awareness, accessibility, availability or affordability.

The main concept was to display, elaborate and visualise the operation of the entire business on a single sheet, a clear-cut “canvas”. The BMC captures the essence of a building an end-to-end technology driven oncology focused managed healthcare Platform. In the BMC, the value proposition is located in the centre of the model, the most important part, where the issues faced by the customer that need to be resolved and the needs we intend to satisfy is clarified. To the right are the three areas characterising the customers (customer relationships, customer segments and channels) and on the other side we list the key activities required for executing the idea, as well as key resources and key partners. The two lower parts of the model show the financial aspects of the business (cost structure and revenue streams).

There is higher need to decentralise cancer care in India through a hub-and-spoke model of service delivery. Cancer patients do not seek care or discontinue treatment due to lack of adequate support and guidance for further diagnosis, treatment, counselling and finances hence, a hub-and-spoke model with a defined patient pathway for the continuum of care is essential, on the back of robust technological framework can address this challenge, improving cancer care outcomes.

The submission demonstrates the key value proposition of using a distributed cancer care model and hub-and-spoke model with a defined

patient pathway for the continuum of care to improve cancer care outcomes.

1.2.3. Testing and Implementation

Submission 6: Designing a Healthcare Technology Platform Framework for Purpose-Driven Oncology in a Developing Country Healthcare Context

The fragmented cancer care delivery in India and the broken patient pathway with accessibility and affordability of cancer care merit the need for participatory frameworks, backed by a well-integrated technology platform. A technology platform based on patient first algorithms and interoperability across the current health infrastructures could enable a connected care ecosystem to achieve improved cancer care outcomes in a developing country healthcare context.

The submission introduces the framework and features of a healthcare technology platform to democratise oncology health care services. The framework relies on participatory systems, patient first algorithms and digital health exchange mechanisms. The proposed platform is built on three key pillars of Technology, Managed Healthcare and Advisory, each with a unique value proposition, yet will be complementary, and tries to address specific requirements across the healthcare delivery value chain, thereby, providing a comprehensive solution to the overall problem of the ecosystem.

We discuss the application of the framework and usage of curated data and robust workflow and rules engine to enable seamless flow of information across all levels of care, while bringing close home care to people. We propose that a technology platform build on a connected care ecosystem could improve cancer care outcomes in a developing country healthcare context.

Submission 7: Implementation of a Technology Enabled Distributed Cancer Care Model in Kerala

With increased global attention to improve cancer awareness and care, the existing models of cancer support are slowly turning into vogue, with

emphasis on a patient centric model that brings affordable, accessible and available care. The intelligent use of distributed cancer care model (DCCM), technology, participatory networks and public-private partnerships can provide high quality, standard, evidence-based and equitable cancer care for people across all walks of life. Kerala with its strong public infrastructure, government initiatives, existing partnerships and trained medical pool of resources is ideal to demonstrate the DCCM model that can be extended to other states and international locations.

The submission describes a technology enabled DCCM using a managed health care architecture and discusses the execution approach to reduce delays in diagnosis and treatment, standardise treatment protocols, provide equitable treatment and regular follow-up across the state of Kerala in India. The submission details a model that will strengthen public-private partnerships and with direct investments made in areas where there is substantial lack of infrastructure and human resources for cancer care. The DCCM will keep patient at the heart of the change and use technology to provide a seamless and decentralised care to citizens.

1.2.4. State of Innovation and Personal Development

Submission 8 presents the discussion and reflection on the research findings and the innovation in to improve cancer care outcomes in the state of Kerala in India.

Submission 9 closes with a personal reflection of my journey as a EngD student and the skills and competences I have gained on this journey.

2. Research background

2.1. Low utilisation of healthcare services

The health system suffers from a low level of public investment, inadequate and crumbling infrastructure, and shortage of skilled human resources, particularly in rural areas (Reddy et al, 2011; Singh et al, 2016). As per the recently released NFHS data, households in India do not generally seek health care from the public sector due to poor quality of care and long

waiting time at government facilities. The problem of follow up and wasting unnecessary time can be overcome by leveraging the power of mobile phones (Peters et. al. 2006; Davey and Davey 2014; Garai 2011). Sharing of data by phones can imply lesser number of visits and the resulting income loss can be minimized.

The major barriers which could undermine the effectiveness of mhealth interventions in India are gender divide in use of mobile phones, lack of infrastructure and social norms. The socio-economic inequalities could determine the use of mobile phones and lead to inequalities in health outcomes. Those who have a mobile might be able to leverage its potential as compared to non-mobile owners.

2.2. Technological intervention as an enabler for improving utilisation

The effectiveness of information technology in improving coverage as well as quality of health care services is well documented (Tomasi et. al., 2004; Peters et. al., 2006). The greatest benefit is usually derived by regions which due to structural deficiencies and resource poor settings have registered low access and utilization. In particular mhealth interventions has the potential to improve maternal and child health outcomes and to reduce the burden of deaths due to easily preventable diseases (Braun et. al, 2013; Sondaal, 2016).

India, world's second most populated country contribute a huge number of maternal and child deaths each year. The health system suffers from a low level of public investment, inadequate and crumbling infrastructure, and shortage of skilled human resources, particularly in rural areas (Reddy et al, 2011; Singh et al, 2016). By adopting low cost -affordable technology, the existing capacity can be augmented. Augmenting the knowledge base by providing guidance and directing patients regarding relevant health schemes can lower the prevalence of diseases.

Experience of other countries indicate that short service messages (SMS) is an effective tool to improve the immunization coverage and to modify the

health seeking behaviour (Domek et. al, 2016; Bangure et. al, 2015; Wakhada et. al., 2012).

2.3. Review of effectiveness of mHealth interventions in emerging economies

Digital health is the convergence of digital and genomic technologies with health, healthcare, living, and society to enhance the efficiency of healthcare delivery and make medicines more personalized and precise. The discipline involves the use of information and communication technologies to help address the health problems and challenges faced by patients. Digital health encompasses many sub-sectors including ehealth, mhealth, telehealth, health information technology and telemedicine. More specifically, the term digital health is defined as "a broad umbrella term encompassing eHealth (which includes mHealth), as well as emerging areas, such as the use of advanced computing sciences in 'big data', genomics and artificial intelligence. (WHO, 2019)

In particular, mhealth technology is being used predominantly in developing countries. As per Labrique and colleagues (2013), 12 uses of this technology can be identified with the most effective being the ability to modify the behavior and to provide information to both supply and demand side stakeholders. On the supply side, the community health workers could be trained to collect data, send reminders, and monitor the schedules related with service delivery. Similarly, on the demand side, the pregnant and lactating women can contact the service providers, book appointments, gain timely information and call out for ambulance services in remote areas.

Given the quintessential role of mHealth services in improving health indices and mitigating the socio-economic inequalities we reviewed the experience of other developing countries.

This review builds on the experience of developing countries to gather evidence about the effectiveness of mhealth interventions and barriers to

such interventions. The aim was to identify the studies for developing countries which evaluated the success of mhealth interventions in increasing the utilization of maternal and child health services (particularly immunization) and barriers which prevented the use among both health care workers as well as beneficiaries.

2.3.1. Data and Methods

Our scoping review followed the five-stage framework developed by Arksey and O'Malley: identifying the research or review question(s); identifying relevant studies; selecting the studies for review; charting the data from them; and collating, summarising and reporting results. (Davis et al, 2009)

Key Terms

Search was conducted using a combination of terms including "SMS text", "immunization coverage", "vaccination coverage", "mhealth", "maternal and child health service utilization", "developing countries" and "maternal and child nutrition".

Data Extraction

A review of literature was conducted based on papers published between 1990 and 2021. PubMed and Cochrane Reviews were used to identify the studies.

The studies were identified based on title and abstract, which were retrieved on the basis of certain key words. The aim was to identify the studies for developing countries which evaluated the success of mhealth interventions in increasing the utilization of maternal and child health services (particularly immunization) and barriers which prevented the use among both health care workers as well as beneficiaries. The research was considered to be rigorous, if the method to evaluate the health intervention involved randomized control trials.

2.3.2. Results

A total of 573 studies were located using PubMed and Cochrane Reviews. After removing duplicates, 141 studies remained. Publications of systematic reviews and protocols for studies were not considered. Finally, a total of 28 studies were selected for review. Most of these studies are based on Randomized Control Trials (RCTs).

2.3.3. Major Findings

2.3.3.1. Equitable access to services

The emergence of mHealth programs and their incorporation into public health system of developing countries have indicated towards their potential to improve the delivery of health care solutions even in the remote and backward areas (Sondaal et. al, 2016; Modi et. al, 2019). Even in the absence of any mhealth interventions women who have a mobile phone are more likely to use maternal health services (Tang et. al, 2019). Clearly targeted interventions can increase coverage many folds. Technology does not discriminate and if the system is working efficiently then it has the power to enhance equity in service coverage among both marginalized and non-marginalized groups (Balakrishnan et. al, 2016).

2.3.3.2. Empowerment of privilege few

Findings from some of the studies indicate that even the health workers who are of low socio-economic status might not have complete information and might be unreliable (Khan et. al, 2018). In such a scenario technology can be used to disseminate accurate information. But, technology can also lead to increase in inequalities in access to healthcare by empowering those who are able to use it. For instance, women in rural areas are less likely to have phone and might be left behind (Lund, et. al; 2012).

2.3.3.3. Use of SMS services

Experience of other countries indicate that short service messages (SMS) is an effective tool to improve the immunization coverage and to modify the

health seeking behaviour (Domek et. al, 2016; Bangure et. al, 2015; Wakhada et. al., 2012). Conditional money transfer for modifying the behaviour leverages the power of mobile payment system to improve vaccination coverage (Wakhada, 2012). Couple of studies based on limited sample size which indicate that mhealth based intervention can be effective to increase immunization coverage (Ganguly et.al, 2018; Seth et. al, 2018).

2.3.3.4. Gender parity

There is a close link between gender equality, dietary diversity and malnutrition. Mobile ownership is a sign of women empowerment. The power of mobile phone can be leveraged to improve dietary diversity among women during pregnancy as well as child health by improving breastfeeding practices (Saronga et. al, 2019).

Table 1: Summary of findings of review of effectiveness of mHealth interventions in emerging economies

	Author	Study design	mhealth intervention	Health indicator	Key findings
1	Kazi et. al 2014	Random sampling method (30 clusters from 3 district, 28 samples were selected from each cluster	SMS based monitoring	Child immunization	SMS based monitoring about vaccination is as effective as interview conducted using phones
2	Domek et. al. 2016	RCT, (N=321 infants whose parents owned a mobile with SMS facility)	SMS text reminders	Child immunization	No significant difference in those who received SMS and those who did not. However, high user satisfaction reported by those who received SMS

	Author	Study design	mhealth intervention	Health indicator	Key findings
3	Bangure et. al 2015	RCT (N=304, 152 each from intervention and non-intervention group)	SMS text reminders	Child immunization	Immunization coverage and adherence to immunization schedule was higher for those in the intervention group
4	Wakadha et. al. 2013	Pilot study in 30 villages, children 0-3 months distributed in 2:1 ratio based on the mode used to transfer money	SMS reminder and Cash transfer	Child immunization	Cash incentive could be an effective strategy to increase immunization coverage and adherence
5	Domek et. al. 2018	RCT (N=1080, based on eligible infants 6 months to 6 years)	Mobile and SMS	Child immunization	Mobile ownership higher in urban areas, most women chosen by families for receiving reminders. In rural areas, landlines were used.
6	Nguyen et. al. 2017	Pre and post intervention	SMS texts	Child immunization	Significant increase in full immunization and measels, participants willing to pay for SMS reminders

	Author	Study design	mhealth intervention	Health indicator	Key findings
7	Menzies et. al. 2020	RCT (N=1594)	SMS meassages	Child immunization	SMS reminders increase adherence where coverage is low
8	Kazi et. al 2018	RCT (N=356)	SMS Reminders	Child immunization	Intervention was successful however not a significant difference observed for 10 and 14 weeks schedule visit
9	Downs et. al, 2019	Focus group (N=6) and Intervention (N=47)	Voice message	IYCF practice	Significant increase in consumption of fish and eggs
10	Flax et. al, 2017	Semi-structured exit interviews (N=195)	Mobile phones, voice and text messages	Breastfeeding practices	Even sharing messasges once a week was associated with higher odds of breastfeeding
11	LeFevre et. al, 2017	Naturalist study design (N=22237)	SMS text	Maternal Health	Delay observed in delivery of messages, effectivenesss of mhealth intervention affected by functoning of the system
12	McBride et.	Intervention study (N=961)	SMS text	Maternal Health	Increase in quality care among

	Author	Study design	mhealth intervention	Health indicator	Key findings
	al., 2018				women from minority groups observed.
13	Modi et. al, 2019	RCT (N=6493)	Web based technology	Maternal Health	Improved coverage and quality of services in remote areas
14	Atnafu et. al, 2017	RCT (N=3242)	SMS and mobile phone	Maternal Health	Utilization of maternal health care services increased however child immunization and contraceptive use did not increase
15	Balakrishnan et. al, 2016	RCT (N=16000)	SMS and mobile phone	Maternal Health	Service delivery increased both among marginalized and non-marginalized groups and was higher in implementation block
16	Lund et. al, 2012	RCT (N=2550)	SMS and mobile phone voucher	Maternal Health	Intervention increased coverage but rural women werer left behind
17	Diese et. al, 2018	Mixed Method Study (FGD N=5; Interviews N=190)	SMS and mobile	Maternal Health	Positive attitude and perception of

	Author	Study design	mhealth intervention	Health indicator	Key findings
					mobile phone for monitoring
18	Khan et. al, 2018	Qualitative study (FGD N=8, interviews N=24)	Mobile phones	Maternal Health	Community health worker considered unreliable as per respondents and a higher willingness among all to receive information through mobile on IYCF
19	Tang et. al, 2019	Cross sectional Study (N=4494)	Mobile phones	Maternal Health	Mobile phone users have higher odds of using maternal health services
20	Hackett et. al. 2019	Cross sectional Study (N=14)	Mobile phone	Maternal Health	Positive effect of mhealth intervention on perception and attitude of beneficiaries and community members
21	Murthy et. al. 2019	RCT (N=2016)	Voice message	Maternal Health	Significant improvement in infant care and maternal knowledge

	Author	Study design	mhealth intervention	Health indicator	Key findings
22	Bangal et. al. 2018	RCT (N=400)	Mobile phone and SMS	Maternal Health	Higher number of ANC visits, institutional deliveries, PNC checkup and lower perinatal mortality observed for intervention group
23	Coleman et. al. 2020	Intervention study (N=87)	SMS text	Maternal Health	
24	Domek et. al. 2019	RCT (N=720)	SMS text reminders	Maternal Health	Caregivers who were sent text message reminders were less delayed for their child's immunization visits and reported high user satisfaction
25	Oladepo et. al. 2021	RCT (N=3440)	SMS text	Maternal Health	Messages increased awareness of immunization dates, assisted in timely completion
26	Mekonnen et. al. 2021	Cross sectional Study (N=456)	Use of mobile text message reminders	Maternal Health	Majority of mothers have the intention to use text message

	Author	Study design	mhealth intervention	Health indicator	Key findings
					reminders for child vaccination
27	Ekhaguere et. al. 2021	RCT (N=600)	SMS reminders	Maternal Health	Paired automated call and text reminders significantly improved immunisation completion and timeliness
28	Dissieka et. Al. 2019	RCT (N=798)	Voice or SMS reminders	Maternal Health	Providing mothers with SMS reminder messages increased the proportion of child immunizations

2.3.4. Conclusion

Our review of literature suggest that mobile phones can be used to achieve rapid improvement in utilization of maternal and child health services and outcomes, and that incentive linked compliance through text messaging can lead to higher immunization coverage. We observe that mhealth interventions are an effective strategy to quickly improve immunization coverage by setting reminders through use of SMS health messages. Similarly, we observe that the maternal and child health outcomes were better among mobile phone users who received message and calls through the mhealth interventions as compared to non-mobile users.

Further research should explore the trends and patterns in mobile ownership and improve the coverage of mobile phones especially among

women so that maximum benefits can be reaped from implementing mhealth interventions.

2.4. Determinants of technology penetration in India

The term "digital divide" refers to the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to their opportunities to access information and communication technologies (ICTs) (OECD, 2001). Digital divide can exist between and within countries. Low developing countries have lagged behind in use of ICTs which has affected their ability to reap the gains from adoption of digital technology (UNCTAD,2017). The demographic and socio-economic characteristics such as age, education, income, gender, geographical location, occupation and infrastructure are important determinants of access to ICTs (Wilson, 2004; Guillen and Suarez, 2005; Huyer et al., 2006; Gill et. al. 2010; Hilbert, 2011). Particularly, in developing countries those who belong to rural areas and marginalized social groups are at a greater disadvantage (UNCTAD, 2013). Digital gap can raise other inequalities as ICTs are predominantly adopted by individuals who are from higher income families, are better educated and young (Van Dijk, 2005).

In India, mobile phones have emerged as a cost-effective tool to overcome the digital divide and to promote economic growth. However, mobile phone ownership is lower among women in India.

Next we explore the extent of digital penetration in Indian households and the distribution of mobile technology across various population groups as well as the role gender plays across both of these dimensions of technology and healthcare access.

The study explores the extent of digital penetration in Indian households and the distribution of mobile technology across various population groups and geographic units in India.

2.4.1. Geographical variation in mobile phone ownership

Using nationally representative household survey data, we investigate the association between mobile ownership and SMS literacy among women with their demographics.

2.4.1.1. *Data and Methods*

The analysis is based on the fourth round of the National Family Health Survey (2015-16) of 122,351 women (age 15-49 years). The data, obtained using a long interview based questionnaire, provide information on maternal and child health indicators. Women have a mobile phone and can read text messages were the dependent variables.

The independent variables included women's education, age, religion, household's social class, wealth quintile and place of residence. Absolute and relative inequalities in mobile ownership and SMS literacy across socio-economic groups have been computed. Multilevel models were calibrated, conditional on the random effects at the level of State, districts and PSUs, to assess the associations.

2.4.1.2. *Results*

Education and wealth status of the women have strong association with mobile ownership and SMS literacy. The probability of owning a mobile and SMS literacy is higher for women who have completed more than secondary education and belong to higher wealth quintiles. Inequalities based on education are particularly stark for SMS literacy. Further, inequalities are present across groups of religion, caste, place of residence and age of women. The associations are validated using multilevel model.

The magnitude of relative inequalities within wealth and education groups indicates that those on a lower socio-economic plane are at a greater disadvantage. Sustained policy efforts are required to make women a part of the knowledge society. Focus on improving educational outcomes and income is the key to increase the adoption of mobile phones and improve digital literacy among women.

2.4.2. Socioeconomic inequalities in mobile phone ownership

The submission highlights the socioeconomic inequalities in mobile phone ownership and digital literacy among women (Age 15-49) in India using an econometric analysis based on NFHS-4.

There are no studies with a large sample size that present the variation in mobile phone ownership and ability to read short message services (SMS) message among women across different geographic levels.

2.4.2.1. Data and Methods

Multilevel models are used to estimate the contribution of geographic levels in explaining the variation in mobile phone ownership and SMS literacy. The data from the fourth round of National Family Health Survey (NFHS) which collected information on health and nutrition indicators was used for our analysis. 122,351 women were interviewed about mobile phone ownership and SMS literacy.

Information on mobile phone ownership and ability to read text messages were used to create the dependent variables. The independent variables included women's education, age, religion, social class, wealth quintile and place of residence. Two and four level variants of a multilevel model, with individuals (level-1) nested within primary sampling unit (level 2), districts (level 3) and States (level 4), were used to estimate the probability of mobile phone ownership and ability to read text message.

2.4.2.2. Results

The results from multilevel model and variance partition analysis indicate that contribution of State and primary sampling unit towards explaining variation in mobile phone ownership and ability to read text message is greater than the districts. The variance estimates are sensitive to the number of levels included in the multilevel model, so relying on estimates obtained for a particular level could lead to a bias.

The findings suggest that understanding the magnitude of inequalities at different geographic levels should be warranted more attention before tackling the socio-economic factors. State estimates should be supplemented with information available for lower geographic levels. It is important to identify the geographical clusters with high and low coverage of mobile ownership and ability to read text messages before implementing mhealth interventions.

Major findings on the are summarised below -

- A strong association between education and wealth quintile with mobile ownership and SMS literacy is apparent.
- The probability of owning a mobile and SMS literacy is higher for women who have completed more than secondary education and belong to higher wealth quintiles.
- Inequalities based on education are particularly stark for SMS literacy.
- Further, inequalities are present across groups of religion, caste, place of residence and age of women.
- Sustained policy efforts are required to make women a part of the knowledge society.
- Focus on improving educational outcomes and income is the key to increase the adoption of mobile phones and improve digital literacy among women.

2.5. Cancer care landscape across the world

Cancer centers across the world operate in a wide range of sizes, scales, and ecosystems. The term cancer centre broadly covers three types of establishment treating patients with cancer, as defined in high-income settings:

- Cancer units are usually dedicated cancer wards within the general hospital setting, including nursing homes and hospices, particularly in low-income and middle-income countries (LMICs)
- Cancer centres are dedicated multispecialty centres that can be stand alone or part of a general hospital complex, including site-specific

cancer centres (eg, haemato-oncology, breast, radiotherapy, hepato-pancreato-biliary, and palliative) often referred to as secondary or district cancer centres (as seen in most National Health Service hospitals in the UK)

- Comprehensive cancer centres are the highest tier and cover multidisciplinary centres that might be stand alone or part of general hospital complexes. These centres deliver not only the full range of cancer care, but also prevention, research, training, and education locoregionally or nationally and are often subject to national and international accreditation processes (eg, National Cancer Institute accreditation in the USA or Organisation of European Cancer Institute accreditation across Europe)

We reviewed the development of cancer centers across the world under the lens of a distributed hub-and-spoke hierarchy construct using technology as an enabler.

2.5.1. Cancer centre development in high-income settings

The development of cancer centres in high-income settings over the past 50 years has been driven by the need to provide increased volumes of care with increased quality, the need to deliver affordable, multidisciplinary care and translational cancer research.

The global engagement of cancer centres in HICs in cancer centre development in LMICs has been modest. The priorities of research funders and national funding for care in HICs and also a separation of agendas in terms of the development of expensive models of care are the primary factors.

Overall, the development of cancer centres and models in HICs provides important lessons for cancer centre development in LMICs including, the delivery of quality optimal care that can be extrapolated to most settings, multidisciplinary working, and the use of local data to drive quality improvements.

2.5.2. Cancer centres in LMICs

The growing burden of cancer in low-income and middle-income countries (LMICs), in particular, has led to an opportunistic increase in the number of cancer centres with little or no regulation or transparent national accountability. Patient migration in search of care has had a profound effect on cancer centre development. Such migration has caused massive financial strain on public cancer centres and has led to an unregulated explosion of private cancer centres.

Cancer centre development in LMICs is driven by a very different set of agendas, contexts, and political motivations leading to ad hoc, often irrational, expenditure on technologies and projects with no effect on outcomes. A further general challenge in cancer centre development is the restriction of funds to support public infrastructure development coupled with the challenges of trying to expand a suitable workforce. Additionally, limitations on research funding have meant that even cancer centres with major clinical and teaching portfolios often produce few research outputs.

The National Cancer Grid of India has established a network of cancer centres across the country and has been a part of the development of new kinds of cancer centres to serve geographically isolated patient populations.

Although efforts have been made to develop comprehensive cancer centres, unless there is governance on the quality of care with adherence to guidelines, these new cancer centres are not likely to improve patient outcomes.

2.5.3. Conclusion

Modern affordable and equitable cancer care and research demands the integration and fair distribution of cancer centres. However, substantial challenges need to be addressed, including ensuring equitability between private and public cancer centres, distributional barriers due to extreme geography or lower development, the scarcity of trained health-care

professionals, and distributional inequality due to the coalescing of cancer centres in the same, often urban, areas.

Crucially, cancer centres need clear public sector strategic direction and leadership that is built on local expertise but with an understanding of international context, by use of the best evidence base to create sound national policies for developing the infrastructure and human resources needed for that context. The reliance on ad-hoc review missions is insufficient for the long-term planning and commitment needed for a national network of public cancer centres.

2.6. Cancer burden in India and the pain points

India has seen a substantial increase in cancer cases over the last few decades, driven by improved reporting and increased incidence rates of cancer in the population. However, a considerable part of the Indian population, particularly the low-income segment, remains under-diagnosed and under-treated given limited accessibility and affordability to health services. Furthermore, only around 5-15% of patients are diagnosed in the early stages of the disease and more than 70% of cancer cases present in locally advanced stages in different regions of the country leading to poor survival (HCG, 2017). The mortality: incidence ratio of 0.68 in India is far higher than that in very high human development index (HDI) countries (0.38) and high HDI countries (0.57) (Mallath, Taylor, Badwe et al, et al). Decreased survival is likely due to a combination of factors such as diagnosis at an advanced stage, limited access to quality cancer care, and the inability of patients to afford optimum treatment (Pramesh, Rajendra, and Sinha, 2014).

Investing in digital health in resource-constrained countries can reduce direct care costs, enhance the access to health services, and improve health outcomes (Lewis, Synowiec, Lagomarsino et al, 2012). A systematic review of digital interventions for Non-Communicable Diseases (NCDs) in India by Hossain and colleagues reported an insufficient number of digital interventions compared to the burden of NCDs in India. Most of the

interventions were for diabetes, followed by neuropsychiatric disorders, whereas none of the included studies focused on cancer, cardiovascular diseases, or chronic obstructive pulmonary disease (COPD), which constitute a large proportion of NCDs in India (Hossain, Tasnim, Sharma et al, 2019). The benefits of the digital revolution in healthcare are still beyond the reach of the rural population suffering from NCDs. mHealth interventions for community health services in many states in India are implemented by Accredited Social Health Workers (ASHA). Unlike in many developed nations, digital health interventions for NCDs have not reached their fullest potential in India (Feroz, Kadir and Saleem, 2018). Digitization in healthcare ensures effective delivery of the services and addresses the challenges of accessibility, lack of healthcare information, and navigation.

2.6.1. The Accessibility Problem

The Cancer Care delivery in India is a highly fragmented delivery value-chain. 'The average patient with cancer in India, health care remains highly privatised, with more than 80% of outpatient care and 40% of inpatient care provided by the private sector'.[i] One of the biggest challenges in the healthcare system is that it vests disproportionate power in the hands of a few – the medical practitioners. Doctors are at the top of the knowledge hierarchy in the system and hence, wield significant power in decision-making, relegating the rest of the players to marginal roles of following orders. A patient, during his journey through the healthcare systems across the world, however, interacts with the doctors just around 10% - 25% of his time.[i] Most of the time, the interaction is with nurses, technicians, support staff and administration. Given so much of the patient experience and wellbeing is linked to what happens in the non-doctor interaction period, it is time to question the power equation in the system.

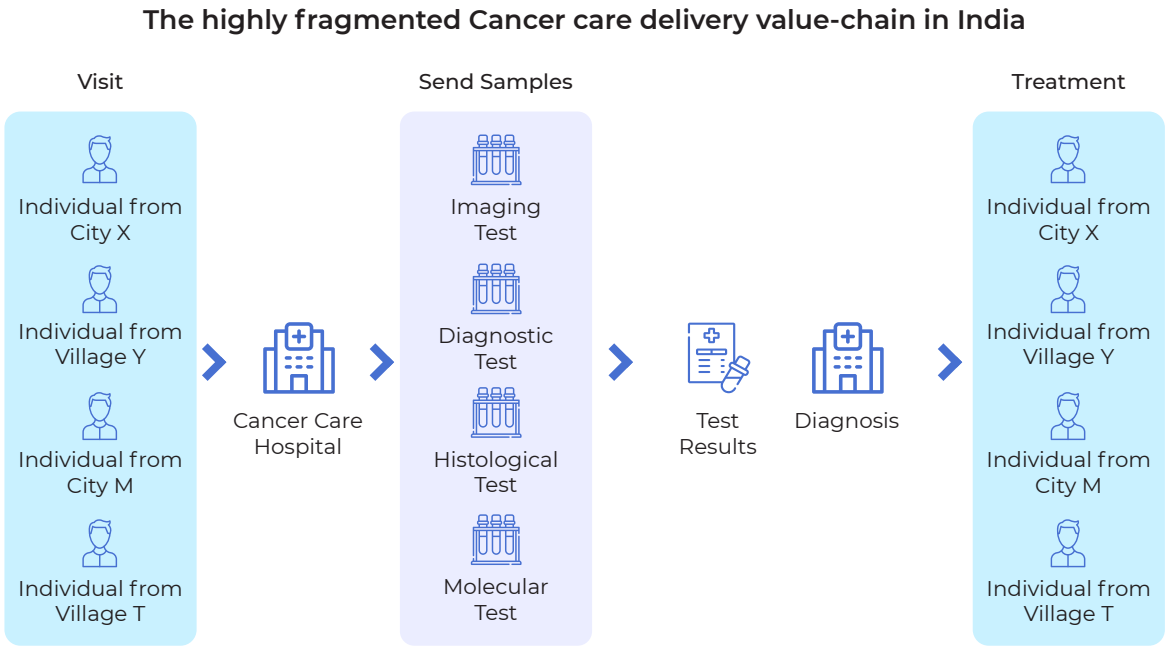


Figure 5: Multiple Touch points in the patient care pathway

Additional problems faced by the patients in the recent times in accessing care and start of treatment:

Non-Standardisation

- Not standardised care at each cancer centre, often driven by the capabilities of the centre e.g., very few centres have access to radiotherapy.
- While the treatment protocols in specialised cancer centres have moved from targeting the tumour to a more molecular and focussed radiation therapy protocols, this knowledge is often not standardised across the cancer care value chain.

Delayed diagnosis/treatment and inconsistent patient experiences

- Inadvertent waiting times at the main cancer centres, where patients from across India visit in the hope of receiving the best treatment, leading to delayed diagnosis
- The time to diagnosis is delayed by the patient having to visit multiple diagnostic centres and even then, does not have access to their results. More than ~70% cancer patients visit a doctor for the first time,

at or past the third stage of cancer, thereby requiring multi-modal therapy, spread over 2-3 years and finally succumb to the disease

- Delay in the start of treatment often happens because of non-existence of treatment centres in the patient's hometown, leading to increased out of pocket expense for travel and stay at the cancer centre

Insufficient capacity and resources

- Absence of specialised care at some of the cancer care often leads to misdiagnosis as in the case of TB and Lung cancer. Both need an x-ray and CT to arrive at the diagnosis, but often missed by an untrained eye
- In the current lockdown scenarios, major public and private cancer centres in the cities were unable to provide patients with scheduled chemotherapy treatment

The delay in treatment or detection of new cases is likely to affect the cancer burden soon. A global modelling study on the impact of the COVID-19 pandemic on surgeries projected that 59.7% of cancer surgeries were postponed in India during the peak 12 weeks of disruption, translating to 51,100 postponed cancer surgeries.

2.6.2. The Affordability Problem

An additional economic burden is put on the person/ patient's is because of an out-of-pocket expenditure incurred by the patient and their family due to lack of insurance and access to any of the government schemes. India has one of the highest levels of Out-of-Pocket Expenditures (OOPE), which contribute directly to high incidences of catastrophic expenditures and poverty. Over 2/3rd of the households who seek care from the private sector incur OOPE in excess of 20% of their annual per capita household expenditure.

The consequences of high out-of-pocket payments disproportionately affect rural and low-income households. Such involuntary expenses are met at the cost of spending on essentials such as food and rent, the selling of assets, use of savings, and the undertaking of greater financial risk through loans from family and landlords.

Distressed financing is significantly high across all public and private hospitals. Nationally, more than 40 percent of households use distress means to pay for cancer treatment in public hospitals. Distressed financing is prevalent in rural areas, with 48.7 and 58.4 percent of households using such funds for treatment in public and private hospitals, respectively.[ii]

When it comes to insurance there isn't enough supportive care, patient knowledge, awareness and patient advocacy related to cancer insurances in India. Eligible beneficiaries report facing difficulties in obtaining the necessary documents for enrolment, and face issues during claiming settlements.

A specialised plan like cancer insurance still needs some convincing in comparison to the more common and regular insurance plans, thus, requiring more convincing to invest for cancer insurances.

Although Publicly Funded Health Insurance Schemes (PFHIs) provide coverage for cancer treatment, there is a need to adequately revise the provider payment rates, such that there is no co-payment from patients.

Government healthcare schemes such as Ayushman Bharat, the Central Government Health Scheme (CGHS), as well as Employees' State Insurance (ESI) need to enhance the amount provided for treatment for cancer. Cancer treatment may go up to Rs. 20 lakhs in some cases, especially if the cancer is diagnosed at advanced metastatic stages – which is the case in about 70% of the cancer cases.

Improving the coverage under the PFHIs shall make the option economically more viable to private hospitals and increase the uptake of

these schemes in private hospital, thus increasing the number of patients who can be treated in these hospitals.

The high rates of catastrophic health expenditure on account of cancer treatment imply that there is a need to enhance coverage of risk pooling mechanisms for reducing reliance on OOP payments. Majority of the OOP expenditure in public sector is for drugs and diagnostics and hence this highlights the need for drugs and diagnostics so that patients are not forced to spend OOP.

In the need to address these problems in delivery of cancer care in India, it is becoming even more important to consider not only the social determinants of health to create a population risk stratification of in-risk populations, but also focus on the triple aim of improving outcomes, controlling costs, and delivering targeted patient experiences across the health care continuum.

2.7. Digital Inequalities in Cancer Care Delivery in India

Global health has improved significantly due to digitization, from early and more accurate diagnosis to increasing access to specialized care, capturing essential information at the point of care for better public health interventions, information delivering personalized care through mHealth, and managing healthcare services in community settings (Lewis, Ray and Liaw, 2018).

However, such advancements cannot be generalized for low public health-resourced countries like India. The application of advanced technological innovations in the low and middle-income countries (LMICs) is relatively low due to limited resources and opportunities to leverage the benefits of digital health (Cho, Lee, Islam et al, 2018; Hurt, Walker, Campbell et al, 2016).

2.7.1. An Overview of the Current Landscape

It is essential to understand how digitization is promoting health among individuals suffering from chronic conditions like cancers. There is a critical knowledge gap about patient-centered applications of digital health

technologies for cancer care in India. We evaluate the knowledge gap on how digital technologies are used to deliver cancer care services and the challenges for large-scale adoption of interventions among the population. The key findings are summarized below -

- Individual - level
    - The use of digital health is particularly relevant for young adults, since they are the pervasive users of technology
    - Some populations are marginalized, like people with low literacy or elderly adults
    - Majority of cancer patients face immense problems in their cancer journey due to lack of accurate and timely information
- Community-level
    - Inequity in digital access due to an increasing digital divide between urban and rural areas is increasing a risk of creating a new class of digitally poor citizens
    - Availability of digital technologies may differ across populations and geographies, affecting the implementation of advanced technological innovations
    - Technological advancements like digital health services may be a greater requirement in the rural settings which can bridge the healthcare gaps
    - The pervasiveness of mobile phone ownership has made messaging through short message service (SMS) the most optimal format to communicate with many patients
    - Failure of continuous internet connection is a major bottleneck for real-time digital capture of cancer screening programmes in rural and hard-to-reach settings in India
- Provider-level
    - Data fragmentation and large gaps in understanding disease development due to long and complex cancer care pathway

- There is a need to standardize the way cancer-related data are collected and stored, transferred, or reported across the institutions involved
- The healthcare industry has been relatively slow in adopting information technology, compared to other industries. Outside of a few urban pockets, India's medical professionals have not yet embraced electronic health records (EHRs)
- Institutions, prefer to invest on improving healthcare facilities, strength of human resources, bed strength and vista of clinical departments rather than investing on Hospital Information System (HIS)

- Systematic level
  - Institutions, prefer to invest on improving healthcare facilities, strength of human resources, bed strength and vista of clinical departments rather than investing on Hospital Information System (HIS)
  - The lack of national digital health structures has led to the development of numerous, uncoordinated sources – these emerge to fit individual, ad hoc needs, often lacking clear standards and duplicating work done elsewhere
  - Declaring cancer as a notifiable disease provides important source of incidence, prevalence, morbidity, and mortality data on cancer. However, the practice of this is non-uniform across the states
  - A critical lack of skills and capacities among healthcare providers, especially in relation to the requirements of data confidentiality and protection, is a major concern for the evolution of digital health.

2.7.2. Technology recommendation for improved cancer care delivery in India

The COVID-19 epidemic has emphasized taking digital technology into the rural areas to be able to provide better and evenly accessible healthcare in

remote areas. Despite the fact that the digital health utilization in the last few months has substantially improved compared to the last several years, there is an increasing digital divide between urban and rural areas, with a risk of creating a new class of digitally poor citizens.

The following are the recommendations for developing a digital initiative in cancer care in LMICs like India.

- Tele-Oncology

The urban-rural health divide can result from poor access and communication between patients and providers. Patients from rural areas especially those who face transportation issues may benefit from telemedicine. The adoption and pervasiveness of mobile technology have expanded the scope of telemedicine.

- Distributed Architecture

There are few emerging hub-and-spoke models for delivering care in cancer with an integrated digital infrastructure for a seamless continuum of care.

- Participatory models

The local and global evidence on digital health must be synthesized to address the gaps and evidence-based policies and protocols must be developed to advance development of digital health solutions.

- Focus on the human factor

All the digital interventions must have a grass-root 'bottom up' approach. Keeping the end users' perspective in mind while adopting digital systems is essential for effective implementation.

- Training of allied health professionals

The comprehensive primary healthcare including services for NCDs consists of management and control of oral, breast and cervical cancers by the health staff of the peripheral health centers. This will help in sub-specialization of cancer thus enabling detection of cancer at early stages.

- Data Sharing and Interoperability

A lack of reliable and easily accessible master data is a core problem that affects current health systems: each vertical program in the government tends to maintain its copy of data that is difficult to keep updated and restricts data sharing across programs (NITI Aayog, 2018). To overcome these challenges, the National Health Stack was established to facilitate the collection of comprehensive healthcare data across the country (NITI Aayog, 2018).

- Text messaging solutions

India is one of the largest and fastest-growing markets for digital consumers, with 560 million internet subscribers in 2018, second only to China (McKinsey, 2019).

SMS is convenient for a patient in many ways. There is no dependence on internet connection. Mobile phone plans today include unlimited texting, so the costs incurred are zero or minimal. Furthermore, with increased access to mobile phones and text messaging, outreach programmes on cancer could be delivered more easily

- Data Safeguards

Electronic Health Record (EHR) can help healthcare providers by enabling reliable storage of the data, make more accurate diagnoses and lower the risk of medical errors or loss of data. The safety and security of personal health data is a major concern in the age of digitization.

- Good Governance

The Ministry of Health and Family Welfare of India (MoHFW) has initiated policy action towards digitizing healthcare by launching the National Digital Health Mission (NDHM) in January 2020 (MoFHW, 2020). It proposes to link systems within private- and public-health provider organizations across primary-, secondary- and tertiary-care value chains.

- Block-chain and Artificial Intelligence

While there is a focus globally for improving population health, personalization of treatment and interventions is increasing. Artificial technologies are increasingly being used for optimizing the performance of digital interventions and customizing cancer care (Qi, Wu, Li, et al, 2007).

2.7.3. Conclusion

Indigenous technology and tools have developed, policy issues addressed and national level programmes are in different phases of implementation. Since health is a state subject it will take some time to get the technology adopted to health system.

For equitable digital healthcare, the need is to have a collaborative approach of all stakeholders and urgently addressing the digital divide adequately.

3. Developing the framework for implementing a technology-driven cancer care intervention in India

Findings from our research on the landscape of cancer care services in India have indicated that policy makers have begun to address how to deliver equality in cancer care and national outcomes through a managed tiered approach to cancer centre development, including improved integration between individual cancer centres to deliver peer review, common guidelines, training, and research networks.

3.1. The concept of technology-driven hub and spoke model for cancer care

Hub-and-spoke models have become an example of an acceptable model that, while exceeding the needs and expectations of its patients, is cost-effective and has obtained operational results with better health outcomes.

Despite being an emerging nation, India takes the top spot in terms of affordability of information technology as well as for having one of the highest number of computer-literate graduates and healthcare workers in

the world. These factors further aid the implementation of hub-and-spoke in India.

Distributed cancer care models with a hub-and-spoke hierarchy in combination with technology is an emerging field. We conducted a review of hub-and-spoke model of cancer care centers across the world.

3.2. Review of technology-driven hub and spoke models

In this review, we study peer-reviewed articles to understand the emerging hub-and-spoke models of distributed cancer care at the back of a technology framework, from across the world.

The objectives of the review, include:

- conduct a systematic search of all available published literature on distributed model of cancer care delivery across the world
- chart data related to technology-enabled models of a cancer delivery in a hub-and-spoke hierarchy
- identify thematic areas that have benefitted from distributed models of cancer care delivery
- identify the challenges and future of distributed cancer care model in India

3.2.1. Data and Methods

Key Terms

Original peer-reviewed articles published in English language journals from January 2010 to October 2021 were obtained from systematic searches of PubMed. We used 16 keywords to identify research articles. The search strategy was a combination of keywords including ‘emerging’ or ‘new’ and ‘technology’ and ‘hub-and-spoke’ or ‘distributed’ and ‘cancer’. Additional terms were added to narrow the scope of the literature findings.

Data Extraction

All the literature findings were merged into the Zotero reference management database and duplicates were removed. After checking for duplicates, the articles were exported to an EXCEL workbook for the review, populated with general article information and abstracts. The titles and abstracts were examined for obvious irrelevant studies for exclusion. Full papers were reviewed to identify eligible papers for inclusion. The details of the reviewed paper is provided in table 3.

Table 2: Summary of the selected studies

Sr	Author	Year of Study	Country of Study	Technology Intervention	Key findings
1	Pramesh et al	2014	India	Technological integration of all centers for seamless patient navigation.	National Cancer Grid of India to improve the quality of services across a network of cancer centers to improve cancer outcomes.
2	Laraia et al	2020	Michigan, USA	Information not available in the article.	Munson's hub and spoke approach (one hub and five spokes) has significantly increased provider availability at the health centres. Nurses and physician assistants at spokes deliver accessible, coordinated, and efficient care for all the oncology patients.
3	Sirohi et al	2018	HICs and LMIC	Describes models for integration between cancer centres to deliver peer review, training, research networks and	Various models of hub-and-spoke emerging in LMICs. PPP models by linking with the government infrastructure are promising. Tiered approach to cancer centre development, including improved integration between individual

				seamless patient navigation.	cancer centres to deliver peer review, common guidelines, training, and research networks.
4	Strother et al	2013	Kenya	Hired personnel, improved the quality of cancer registry.	A hub-and-spoke model with 50 sites for care delivery, AMPATH-Oncology program delivers cancer care in a resource - constrained setting. Supported by HICs, research and capacity of nurses and physicians for screening for common cancers, and administer chemotherapy.
5	Chalkidou et al	2014	Global	Digitisation of services for better management of data and seamless navigation.	Governments, which are the main financial stakeholders in health-care services should move towards universal health-care coverage, need to invest in their own national institutions for decentralising cancer care.
6	MacDonald et al	2010	USA	Growth enabled by information technology, with Web conferencing and videoconferencing.	Leveraging on a network of community - based health center partnership for delivering genetic cancer risk assessment (GCRA) for targeted therapy and cancer screening and prevention.
7	Harris et al	2017	North Carolina, USA	Cloud-based IT system in addition to utilizing custom WebEx and telemedicine approaches.	One hub and five spokes provide peer-to-peer review for radiation therapy providers. Using the hub-and-spoke model to support the peer review process demonstrated that a process of quality review can work at the community level, and

					help to standardise care.
8	Mishra et al	2015	India	Uses teleconsultation, cancer registration, tele-education, telepathology, and teleradiology.	OncoNET India project is under implementation which will network 27 Regional Cancer Centers (RCCs) with 108 Peripheral Cancer Centers (PCCs) 155 hospitals to facilitate national cancer control programmes.
9	Morgan et al	2018	Global	Tertiary center to full range of cancer equipment and technology to regional centers.	Developing a National Cancer Center with a network of several regional cancer centers (RCCs) to achieve improved patient access to management, diagnosis, and treatment of cancer.
10	Sabesan et al	2018	Australia	Chemotherapy at primary centers under supervision of chemotherapy-proficient nurses, using videoconferencing.	The Queensland Remote Chemotherapy Supervision (QReCS) model (2 hubs, 6 spokes) enables rural nurses to administer chemotherapy in smaller rural towns under supervision by health professionals from larger centers using telehealth. Approach feasible and results in enhanced access to chemotherapy services with an acceptable safety profile.
11	Chan et al	2015	Australia	Teleoncology model for managing cancer patients in rural towns.	Finds on significant difference in the dose intensity and toxicity profiles for patients undergoing chemotherapy at a tertiary cancer centre with those for patients treated in secondary centers, supervised by the same medical

					oncologists via teleoncology.
12	Khakwani et al	2014	England	Information not available in the article	Findings reveal the need for more access to lung cancer surgery facilities. Patients first seen in a surgical centres have high resection rates than patients first seen at the non-surgical centres, esp. in surgical centres with larger catchments
13	Geiger et al	2020	USA	Information not available in the article	NCORP network of seven Research Bases develop and conduct studies and 34 Community Sites and 12 Minority/Underserved Community Sites implement the studies and accrue patients and participants. One Research Lead in each site for coordination.

3.2.2. Results

In Figure 6, the PRISMA diagram summarizes the literature review process. We collected 285 articles from our literature search. Once the duplicates were removed, we had 270 articles for further review. For the review process, we used an Excel workbook populated with general article information, title and abstracts.

After completion of the abstract review, 238 articles were excluded due to being irrelevant. Out of the 32 articles for full-text review, 6 were excluded due to non-availability of full-text articles. 15 full-text articles were excluded due to being irrelevant. We identified 11 articles of interest.

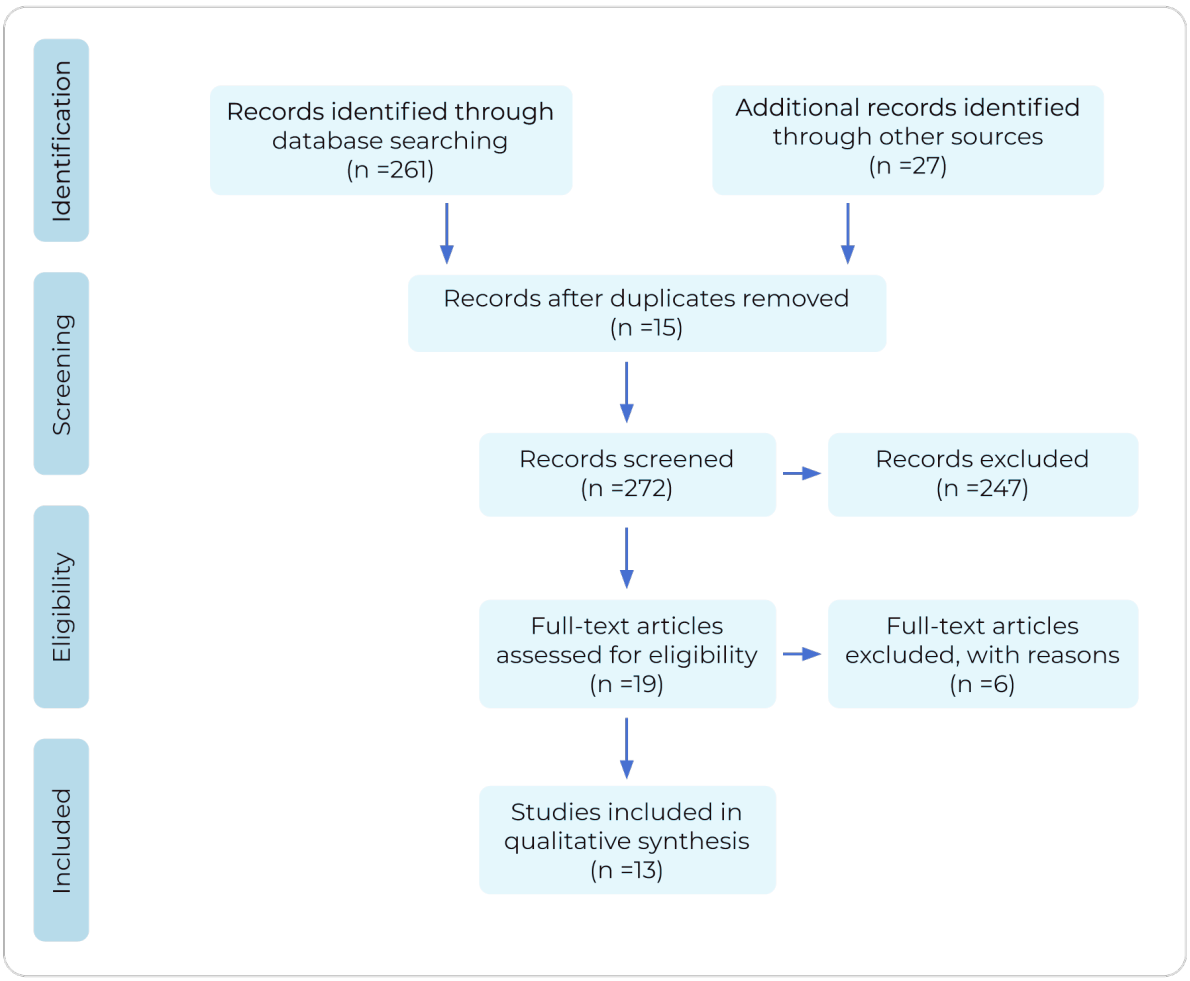


Figure 6: PRISMA diagram for review of technology-driven hub and spoke model

3.2.3. Key Observation

- Our analysis of both HICs and LMICs show hub-and-spoke models in cancer care as an emerging area, especially in the LMICs.
- Among LMICs, India is a leading example, with emerging hub-and-spoke models involving government infrastructure through public private partnerships, as well as through strengthening of the government's own public health system to deliver cancer care services even in low resourced settings
- Teleoncology has further facilitated the development of a distributed model of cancer care. The result of implementing such a model of cancer care delivery has enhanced access to chemotherapy services

- Collaborations between cancer centres in HICs and those in LMICs have also played a key part in the development of translational and clinical research, including clinical trials.
- The global engagement of cancer centres in HICs in cancer centre development in LMICs has been modest. This situation reflects the priorities of HICs in research rather than the development of networked, collaborative models of care to address the cancer disparities.
- Expanding cancer research to community settings to include more diverse patient population treatment in a variety of healthcare settings can accelerate accrual to cancer clinical trials and reveal findings which can be more generalizable and relevant
- Robust training programmes have helped in upskilling and task-shifting of the health workforce bridging the manpower gap in cancer care, providing the right level of patient care at the right time.
- In HICs, task-shifting to nurses and physicians to deliver accessible, coordinated, and efficient care for all oncology patients has proved to be effective in improving patient satisfaction and increasing the availability of care providers
- Growth enabled by information technology, with videoconferencing for telemedicine and Web conferencing for virtual tumor boards and teleoncology for chemotherapy and radiation therapy has helped to manage cancer cases in non-metro areas.
- This hub-and-spoke approach for cancer care delivery through the public health system ensures access to the right facilities for people from all corners of the country

3.2.4. Conclusion

It is clear from our findings from across HICs and LMICs that hub-and-spoke models improve cancer care across the patient's journey, by virtue of making cancer services more accessible, affordable, coordinated and

ensuring fair distribution of cancer services, ultimately improving cancer outcomes.

Hub-and-spokes can reduce the high amount of patient migration to tertiary cancer centers in cities for treatment directly impacting the known preventable problems of financial, transport and cultural constraints in cancer patient pathways. HICs have widely delivered cancer care services and conducted research using the hub-and-spoke approaches, involving genetics as well, through a mix of technological models.

As hub-and-spoke models are emerging in India, it needs to take into account the learnings and mistakes made by HICs. Crucially, this development should align with the political and cancer centre leadership, the cultural and socio-economic factors, and be within the context of national policy for health systems, health human resources, and infrastructure.

Cancer patients discontinue treatment due to lack of adequate support and guidance for further treatment, counselling and finances hence, a hub-and-spoke model with a defined patient pathway for the continuum of care is essential. A centralised care coordinator for follow up, backed by a physical on-ground support can reduce patient dropouts and impact cancer outcomes.

We build the the essence of a building an end-to-end technology driven oncology focused managed healthcare Platform using the Business Model Canvas.

3.3. Business Model Canvas

It is evident that the approach to finding a solution to cancer care inequity in India needs to ensure incorporation of technological elements in its foundation.

As per our findings, technology has facilitated the development of a distributed model of cancer care delivery, and the result of implementing such a model of cancer care delivery has enhanced access to services. Technology has facilitated the development of a distributed model of cancer care (Chan, Larvins, Evans et al, 2015).

This section aims to to create a blueprint to define the business to describe a technology-enabled hub-and-spoke model of cancer care in India using the Business Model Canvas. It shall look further in assessing the strategy, planning gaps, exposure to risk and help in laying down the execution steps required to take the idea to market.

The BMC was applied and tested successfully in many organisations (e.g. IBM and Ericsson), to describe and manipulate business models to create new strategic alternatives (Barquet A, Cunha V, Oliveira M et al, 2011). León and colleagues used the BMC to design a model of digital ecosystem for healthcare and wellness (León, Nieto-Hipólito, Garibaldi-Beltrán et al, 2016).

The BMC diagram shown in figure 12 summarises a Technology-Enabled Hub-and-Spoke Cancer Care Business Model.

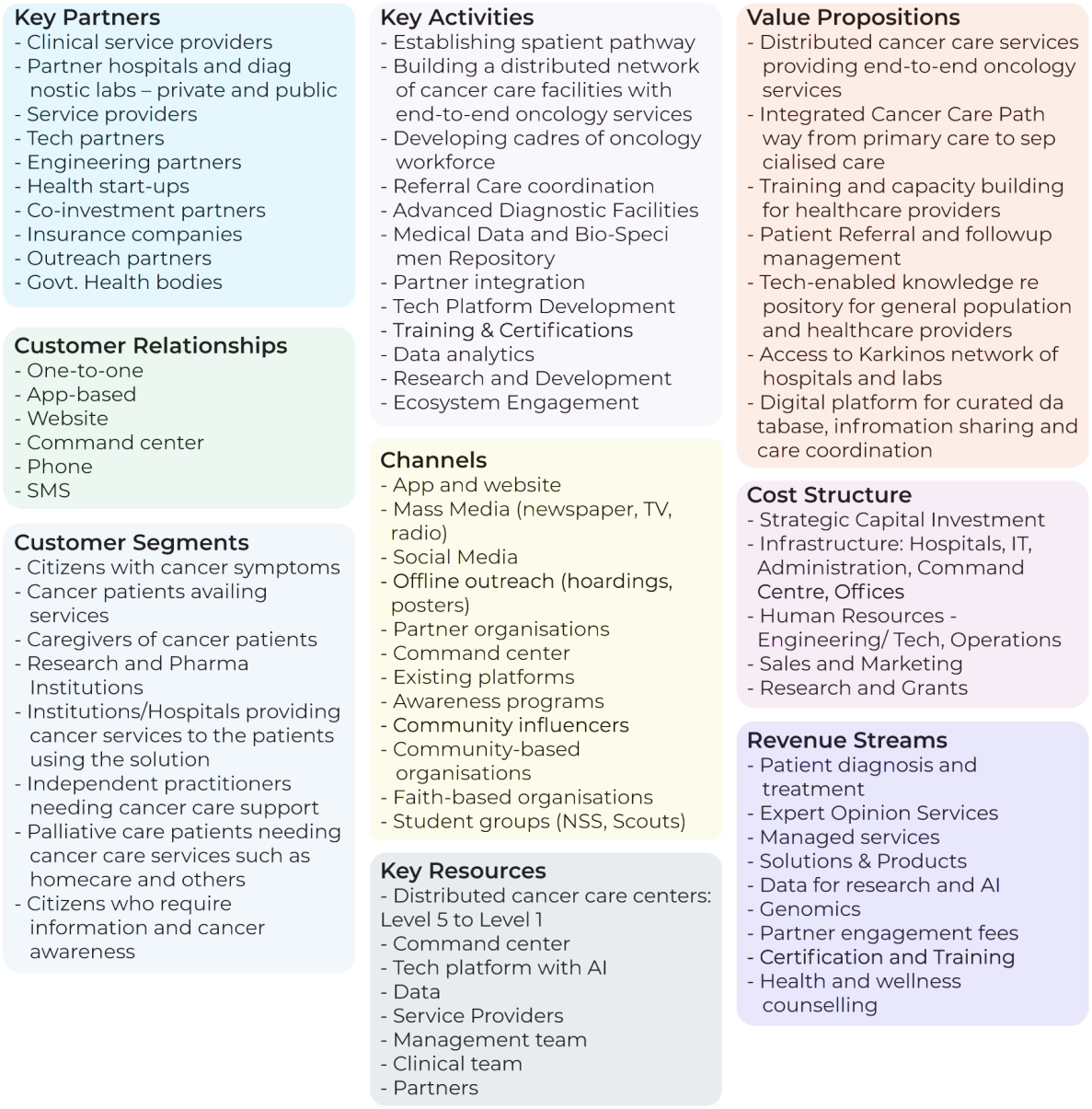


Figure 7: Business Model Canvas for Technology-Enabled Hub-and-Spoke Cancer Care Business Model.

3.3.1. Customer Segments

The customer segments as part of the services are:

a. Citizens with cancer symptoms

b. Cancer patients availing services

c. Caregivers of cancer patients

d. Research and Pharma Institutions
e. Institutions/Hospitals providing cancer services to the patients using the solution
f. Independent practitioners needing cancer care support
g. Palliative care patients needing cancer care services such as homecare and others
h. Citizens who require information and cancer awareness

3.3.2. Value Proposition

a. The Platform proposes to enable the following value propositions to target our key customer segments
   i. Create knowledge repository of information and curated data base about Cancer
   ii. Citizen outreach programmes
   iii. Create Early Detection Campaigns that cover the entire state population
   iv. Provide cancer patients with a solution that helps in their treatment pathway through a network of diagnostic and treatment centres
   v. Provide an Integrated Cancer Care Pathway from Treatment to Survivorship and palliative care
   vi. Patient Referral and follow-up management through a Command Center
   vii. Access to the network of hospitals and labs
b. In addition to the targeted Value Proposition for each of our customer categories, the following shared services are identified that will enable to plan centrally and deliver locally various services that we have identified for the oncology care.

i. Distributed Cancer Care Network built on constantly evolving Knowledge Architecture driven by big data and predictive analytics data mesh.

ii. Unifying the healthcare ecosystem partners onto a single connected platform to drive cashless, seamless, paperless and presence less cancer care delivery.

iii. Reduce cost of cancer care for patients by improving efficiency, coordinate care across the network and removing redundancy in care process driven by technology Identify and extend affordable.

iv. Financial assistance programs for covering cancer care cost for our patients.

v. Using technology and genomics to find continuous ways to improve quality of life.

vi. Digital Information Spine - Plan Centrally Deliver Locally Training Human resources to enable last mile delivery of cancer care

vii. Ability to customise treatment plans based on the patients in care and allow for a care coordination of the workflows

3.3.3. Channels

For customers exposed to smartphone technologies and internet, the solution will be delivered to customers via:

c. App Store

d. Website

e. Social Media

f. Application Programming Interfaces (API) & Software Development Kits (SDKs)

g. Partner Organisation Websites/ Apps

Customers will also be able to find the solutions via:

a. Distributed Cancer Care Network including the National Cancer Grid
b. Mass Media - newspaper, TV and radio
c. Offline advertisements - hoardings, posters and banners
d. Partner organisations – existing outreach channels
e. Public health system of the respective state – Information Education Communication (IECs)
f. Community awareness programs by front line health workers like Accredited Social Health Activists (ASHAs), Anganwadi Workers (AWW) and Auxiliary Mid-Wife (ANM) of India's National Health Mission
g. Endorsement by Community influencers - celebrities, politicians, sportspersons, cancer survivors
h. Outreach through civil societies – Non-Governmental Organisations (NGOs), Community-based organisations (CBOs), and Faith-based organisations (FBOs)
i. Student groups – National Service Scheme, Scouts and Guides

3.3.4. Customer Relationships

Interpersonal communication, digital, remote, tele call and SMS communication will be established to reach various customer segments. To enable this, various mechanism will be adopted.

Robust citizen outreach programmes will capture the attention of people across various segments. For the rural communities, the front-line health workers such as Community Health Officers (CHOs), Auxiliary Mid-Wife (ANM), Multi-Purpose Workers (MPWs) and Accredited Social Health Activists (ASHAs) of the public health system

will be leveraged for interpersonal communications with the customers on cancer related information and the integrated services.

Customers will get onboarded into the Platform using various community engagement initiatives. Customers will find out about the cancer services as part of the Non-Communicable Disease (NCD) awareness and screening process being conducted at a population level with the help of the partners. The network of partners will enable promotion of the Platform and its services through their existing outreach channels.

The customers apps and support services like SMS and social media channels will be used to interact with the patient regularly through the cancer pathway. Each of these interactions provides an opportunity to influence the customer's perception about the quality and value of care.

3.3.5. Revenue Streams

Revenue streams identified as part of the Platform are:

a. Patient diagnosis and treatment
b. Expert Opinion Services
c. Managed services
d. Solutions & Products
e. Data for research and AI
f. Genomics
g. Partner engagement fees
h. Certification and Training
i. Health and wellness counselling

3.3.6. Key Resources

a. Physical centres
b. The technology solution
c. The Command Centre

ii. Telecommunications
iii. Appointment Support
iv. Alerts & Reminders
v. Care Coordination
vi. Education & Training
vii. Virtual Tumour Board (VTB)

d. Machine Learning and Artificial Intelligence
e. Clinical/ data repository
f. Human Resource
    i. Consulting Board of Experts
    viii. Practitioners (Doctors, Nurses, Allied Healthcare Workers)
    ix. Radiologist, Pathologists
    x. Deep Technology Engineering Team
    xi. Partner Engineering Team
    xii. Management Team
    xiii. Community Health Workers
    xiv. Cancer survivors
    xv. Partner Management
    xvi. Patient Engagement Coordinators

3.3.7. Key Activities

The most important strategic things the Platform must do to make the business model work and are directly relatable to the value proposition are:

a. Care Pathway Research and Development
b. Standardising patient pathway
c. Building a distributed network of cancer care facilities with services including awareness, screening, early diagnosis, treatment and palliative care

d. Referral Care coordination
e. Technology Solution Development
f. Advanced Diagnostic Facilities
g. Medical Data and Bio-Specimen Repository

   The data captured will include:

   i. patient demographics
   ii. medical history of the patient and family
   iii. known risk factors
   iv. clinical information, including step-by-step outcomes (in-patient and out-patient data)
   v. laboratory-test results
   vi. radiology imaging
   vii. molecular profiling and next-generation sequencing data

   In addition, the biorepository will cryogenically store live samples of:

   i. tumor biopsies
   ii. adjacent normal tissue
   iii. blood serum; and
   iv. saliva

h. Genomics
i. Data Management
j. Research and Development
k. Ecosystem Engagement
l. Training & Certifications
m. Developing cadres of oncology workforce

n. Partner integration

3.3.8. Key Partnerships

The services will provide evidence-based care across the health care ecosystem through partnerships to provide services across the patient clinical pathways for common forms of cancer. To enable the ecosystem, partnerships will be established with the following entities:

a. Oncologists, Radiation Oncologists, Surgeons and Clinical Experts to deliver standardized high-quality oncology care, guide protocol development and execution

b. Tertiary Care, Secondary Care, Primary Care Centres, Accredited hospitals, End-of-life care facilities, Apex Oncology Centre, Cancer Research Institutes, Home Care & Elderly Care Groups to share services and enable a distributed cancer care delivery nearer to patients' homes and enhance the model for an equitable and accessible care

c. Tata Memorial Hospital in Mumbai, or Tata Memorial Centre in Kolkata to define standard pricing constructs for oncology services at optimal rates in order to reduce the cost of cancer care.

d. The Network hospitals and diagnostic labs – across private and public ecosystem in tier 1/2/3 cities across India to create standard patient experiences from early diagnosis to end of life care

e. Service providers offering equipment, machinery, medicines, construction, etc. at reduced costs in return for longer contracts, and avenues for co-branding

f. Research Institutions for sharing biomedical data to be used for analysis and innovation in cancer research ultimately improving cancer care outcomes

g. Insurance partners for offering affordable solutions that meet needs of the patients, becoming a market differentiator and a profitable sustainable offering for insurers.

h. Health Tech Startups, Healthcare Technology Vendors, Cloud Infrastructure Providers to enable cancer care services across the State

i. Voluntary Health Groups network to engage communities and bring awareness about cancers and conduct screenings through L4 centres.

j. Co-Investment Partners to invest in the Platform with a viable return on investments over several years

k. Government Health Institutions and Health Schemes to leverage on existing network of infrastructure, workforce, cancer services, engagement networks, insurances assistance and referral mechanism.

3.3.9. Cost Structure

a. Strategic Capital Investment

b. Infrastructure

c. Information Technology

d. Command Centre

e. Offices

f. Human Resources

g. Sales and Marketing

h. Research and Grants

3.3.10. Conclusion

There is higher need to decentralise cancer care in India through a hub-and-spoke model of service delivery. A hub-and-spoke model with a defined patient pathway for the continuum of care is essential, on the back of robust technological framework can address this challenge, improving cancer care outcomes. The vision is to create technology-enabled patient-centric cancer centres to deliver standardised and affordable care close to patients' homes.

3.4. Technology framework

3.4.1. Guiding principles for the Technology Platform

It is important to make the cancer care delivery model to be participatory in nature rather than having proprietary partnerships. The participatory approach requires to be supported by clear design guiding principles for the technology platform.

a. Patient centric
b. Information rich and insightful
c. Standard based and Interoperable
d. Scalable and extensible
e. Secure

3.4.2. Three pillars of Technology Platform

The health care technology platform will be built on three key pillars – Technology, Managed Healthcare and Advisory, each with a unique value proposition, yet will be complementary.

3.4.3. Technology

The technology platform will provision capabilities that will allow the patients to get an accessible and affordable cancer care close to their geographical location. The platform will be driven by a knowledge

algorithm that will enable the delivery of the treatment protocol. The platform will enable learning solutions not only for the patient but also the clinicians while following an outcome driven care delivery model.

Some of the key components of the cloud platform include:

3.4.3.1. Clinical/ data repository

A key differentiator for creating standard patient experiences is holding the right curated data to help clinicians provide effective and efficient treatment either remotely or in-person. The data will also be critical for health care providers to introduce preventive measures and counselling activities for citizens based on patient data such as family history, shared and curated medical records, demographics and other relevant factors. The data repository will enable participatory ecosystem partnerships and create unique patient experiences.

3.4.3.2. Workflow Engine & Rules Engine

The engine manages business processes, facilitates the flow of information, tasks and events for the technology platform. The engine will help us deliver workflow design, route and monitor routine tasks for effective coordination between health care services and cloud users.

3.4.3.3. Machine Learning/Artificial Intelligence Models

The data sets for oncology are growing in volume in each year, which include radiographic, histologic or electronic health data or genomics, which open an array of opportunities to gain a deeper understanding of cancer and provide personalised care for patients. As of 2020, the volume of medical knowledge is estimated to double every 2 to 3 months and given the manifest impossibility of one individual retaining all the knowledge, modern medicine increasingly requires clinicians to effectively digest and make practical use of the volume of data available to them. For structured data and standard processes,

the cloud platform will introduce analytics that leverages machine learning and artificial intelligence models. Patients who use the cloud platform will get smart suggestions based on their patient records and timely notifications. Conventional examples of such constructs include Amazon's Alexa or Google GPS software among others.

3.4.3.4. Curated Knowledge base

A curated knowledge base with expert annotations, therapy findings, similar matches with clinical and treatment information will help clinicians suggest treatment options while highlighting similar anonymised cases where a similar treatment was provided and successful. A centralised knowledge base with partnership with existing digital solution providers and existing national databases through use of APIs will help systematically build patient data sets across the country and beyond. The data sets will in turn help with research and help enable solutions to provide affordable treatment.

3.4.3.5. Notifications

An intelligent notification feature will be available for clinicians, patients and other cloud users. With REST APIs and Fast healthcare interoperability resources (FHIR) standards, the cloud platform can connect internal and external facing apps such as research, health and diagnostic platforms using health information exchange and clinical research services.

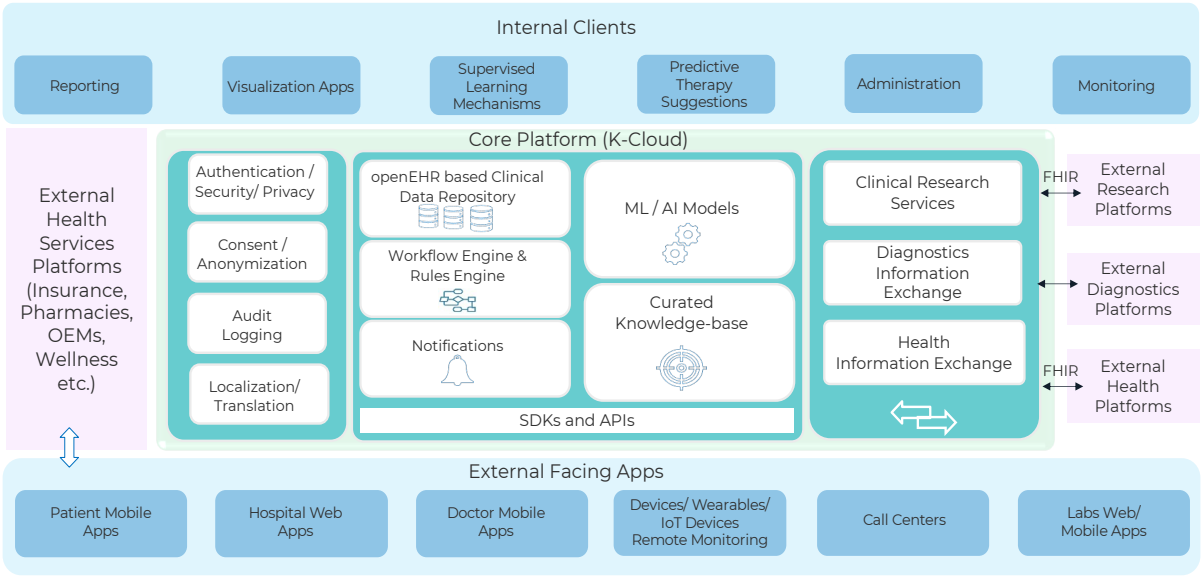


Figure 8: Technology Platform Key Components

Source: Karkinos

3.4.4. Managed Healthcare

Managed Healthcare that leverages the existing unutilised capacities and human resources across the country that are trained for providing evidence-based care for cancer types which account for 80% of the cancer diagnosed in India - breast, cervical, oral, lung, head and neck. A technology platform can enable the development of shared services - digital pathology that will for instance reduce the time to report a histopathology sample, surgical skills that will be available across the network.

The technology platform can also integrate and ensure seamless information flow across all care levels across the distributed cancer care model, that is based on a hub and spoke and further spoke model from an apex (L1) centre as a hub to an early diagnosis facility (L4), which will be a health and wellness centre equivalent that will enable surveillance and early detection of cancer in a community driven model.

There are good reference examples where technology and tele oncology has facilitated the development of the distributed model of cancer care. For example, the Queensland Remote Chemotherapy Supervision and Townsville Tele oncology Network have implemented tele oncology models

where chemotherapy is administered to patients in smaller rural towns under supervision by health professionals from larger centres using tele oncology. The result of implementing such a model of distributed cancer care delivery has enhanced access to chemotherapy services. As per the findings, administering chemotherapy in rural towns under the supervision of medical oncologists from larger centres via tele oncology is safe, provided that rural health care resources and governance arrangements are adequate.

3.4.5. Advisory

Advisory for enabling connected care ecosystem of reliable service partners that are able to deliver care to the patients in a participatory manner. The Advisory will provide strategic support and enable technical and knowledge partnerships between different ecosystem players to enable an optimal utilization of existing resources.

To work with a number of public-private partners, who may have IT systems with varied levels of maturity, the technology platform will need to have data frameworks that ingest, integrate, validate & normalise a variety of data ranging from a standard based clinical record to an unstructured and non-semantical care record from multiple sources. This will help transform the data within a scalable, secure cloud infrastructure.

It is well understood that achieving the full potential of precision medicine for all cancer patients depends on the sharing of patients' genomic and molecular data and clinical information. An open structured technology platform can support cloud, clinical care intelligence microservices and data repository across all connected and partner organisations.

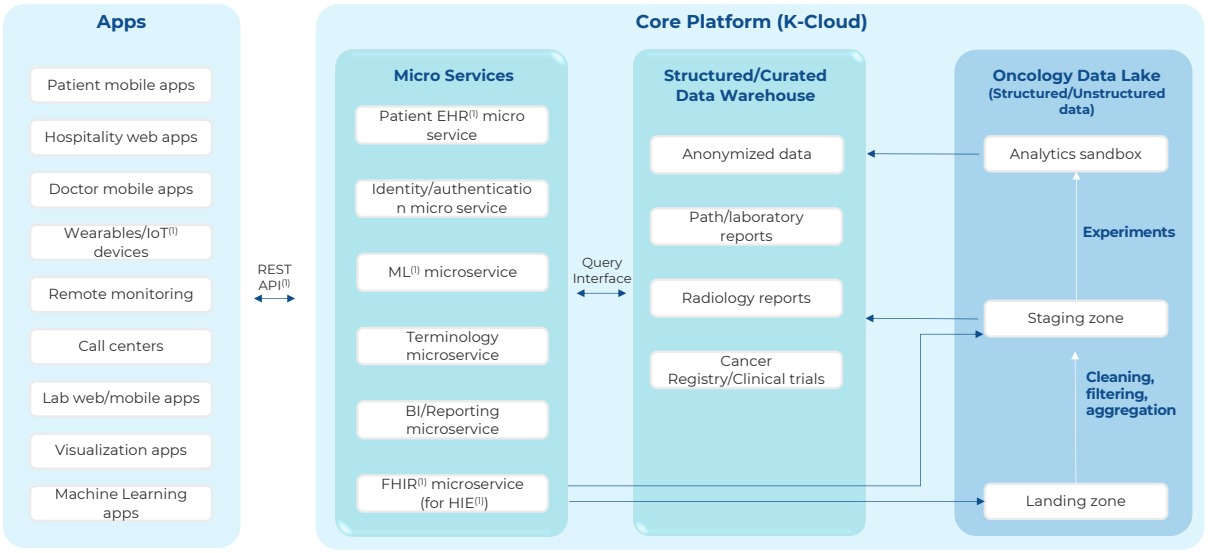


Figure 9: Schematic diagram

Source: Karkinos

In the above schematic, the process for data curation is demonstrated. The data from various partner sources such as web, mobile, machine learning applications, call centres etc. will reach the landing zone using microservices and passed to the staging zone after filtration and aggregation of data. For hospital organisations with mature IT infrastructure, the data may be passed to the Staging zone directly. The curated data is passed to the analytics sandbox within the cloud data warehouses, each of which act like purpose driven knowledge repositories to provide contextual insights.

The technology platform will allow health care organisations and partners to create Precision Dashboards using anonymised data based on the patient context of care, staging and characteristics of cancer. The platform will provide information nudges to care providers linked to the connected network based on a learning algorithm that derives its rules and workflows from the standardized guidelines of care from various sources.

The fragmented cancer care delivery in India and the broken patient pathway with accessibility and affordability of cancer care merit the need for participatory frameworks, backed by a well-integrated technology platform. A technology platform based on patient first algorithms and

interoperability across the current health infrastructures could enable a connected care ecosystem to achieve improved cancer care outcomes in a developing country healthcare context.

3.5. Central Command Center

Command center is considered the central nerve center of the end-to-end cancer care journey that is envisioned. It is the central communicating hub between all entities within and outside the organization. This is the hub that all entities reach out for the data and processes.

The initial focus of the command center will be solely to provide patient services. Internal logistics in term of human resource bandwidth, procurement, internal supply chain is not considered as part of command center at this time.

3.5.1. Command Center Functionality

The functionality of the command center in its entire form is represented currently as following:

1. Patient Services: This is the most important function of the command center. The principle is to provide seamless service to the patient. In order to provide comprehensive and seamless service to the patient, a number of various data sources have to be referred and a number of experts and healthcare workers have to be involved in the care team. Central command center will be used to refer to the data required for the care team and the patients and enable communication between them. Following is the functionality that will be used for seamless patient services:
    a. Care schedule – appointment, reminders
    b. Care related communication – care path planning, consultation, diagnosis, screening, etc.
    c. Communicating with the doctor (multichannel)
    d. Patient engagement – Follow up post care

e. Logistics support – Provide care at home – nursing care, nutrition, infusion, rehab, etc.

f. Training / education

2. Internal collaboration: Various teams within Karkinos will use the central hub to access data and communicate between each other. Following is the functionality that will be used for internal coordination and collaboration:

    a. Clinical analysis –

        i. Care decisions (Patient care path planning) – communication between the expert to decide the line of treatment and the relevant details. This will be part of virtual tumor board.

        ii. High risk patients CoE – Research and care collaboration

        iii. Remote diagnosis – all aspect of remote diagnosis (teleradiology, telepathology, etc.) will be conducted via the command center.

        iv. Data handover, transfer between care representatives, clinicians, experts.

        v. Internal logistics – human resource bandwidth, material procurement, transfer, etc.

        vi. Research – Collaborate with various research organization to implement clinical study and provide data required for further analysis

3. Partner Integration:

    a. Hospital / clinic integration – Transferring the patient information, schedules and payments for patient care. All necessary technology, interoperability will need to be achieved. Logistics coordination for any materials, supply, patient samples, etc.

b. Lab integration – Samples logistics information and report / insights sharing, patient information transfer.

c. Imaging center integration – Images and insights sharing, patient information transfer.

d. NGO partnerships – Schedules of screening camps, logistics coordination, care coordination for patients, education / learning, etc.

e. Government – Data integration with national registry, – Schedules of screening camps, logistics coordination, care coordination for patients, education / learning, etc., research collaboration.

f. Govt / Private regulatory – PMA, adverse events, statistics, etc.

4. Documentation / Transcribing – This is used to define the workflows of the command center. Each service will have the stakeholders and the process workflow defined for it. Every process will need adequate person bandwidth of specific skillset, infrastructure resources and right data. Each workflow will be defined and refined by performing analysis of the efficacy and optimization. Once the workflow is standardized, it can be automated to reduce human bandwidth required for it. Each of the workflow will required the single source of truth of data that is validated and authenticated for providing streamlined care to the patient. As such the function is broken down into following:

    a. Design workflow for each function (workflow process, stakeholders, infra requirement, data requirement)

    b. Analysis of the workflows and refinement

    c. Data input for patients and quality check for authentication and validation

    d. Automating the workflows – Left Shift

5. Karkinos operational review – This is the only function that is not related to the patients but to provide the operational review of Karkinos. This will require providing the data for operational analysis (financial, bandwidth, customer satisfaction, etc.). The operational analysis parameters will be defined at a later date.

3.5.2. Patient Services

The fundamental objective of command center is to bring all knowledge and resources together at central location so that the patient can get streamlined care. To that end, the patient services offered need to be enabled well with the command center construct. Following are the patient services offered currently.

1. Screening services: Preventive, routine screening for citizens. This can be done at remote locations and the risk stratification will be performed by the experts. The phased process of screening and the associated workflows will be defined. Command center will facilitate the service by tracking the screening workflow and maintaining the data for each patient.
2. Diagnosis: This service will be provided for patient coming to the hospital / clinic with some complaint. The line of diagnostic testing and related workflows will be defined. Command center will assist in recording the sequence of diagnostic tests, ingesting all data and contextualizing it for expert to refer to. The adequate, authenticated data will be made available for the experts for the analysis, tumor board, etc. The patient will be assisted with the schedule, appointment, follow ups, payments, reports, etc.
3. Treatment: This service is facilitated by command center by recording the line of treatment for the patient based on expert analysis and tracking the treatment. The adequate, authenticated data will be made available for the experts for the analysis, tumor board, etc. The

patient will be assisted with the schedule, appointment, follow ups, payments, reports, etc.

4. Consulting: Second opinion – This service will be facilitated by storing all patient data, making the right data available for the consultants / experts for decision making and treatment planning. The adequate, authenticated data will be made available for the experts for the analysis, tumor board, etc. The patient will be assisted with the schedule, appointment, follow ups, payments, reports, etc. further if requested further by the patient.
5. Patient navigation: This service will be facilitated by the command center by making the patient journey information (historical information – multiple sources time sequenced and contextualized, treatment plan, progress, patient support needed, activities planned, etc.) to the experts. The calling executives will work with the patients to provide assistance on the activities planned, the experts will use the information to analyze the patient progress and refine the course of action.
6. Home care – This service will be supported by the command center by supporting the patients with various queries, guiding them with a lot of activities and supporting them with home tasks (sample pickup, deliver medications, nutrition, education and training, etc.). Command center will also provide the resources view to the internal stakeholder to ensure that the supply chain and the logistics of the materials, consumables and other resources are available for the home care. It will provide the interface with the procurement and supply chain engine.
7. Care concierge – Care concierge is a service similar to patient navigation. The service will be supported by the command center by providing complete patient data and information to the person supporting the patient. The same person will be able to help the

patient with the schedule, appointment, follow ups, payments, reports, etc.

3.5.3. Stakeholder Roles Utilizing / Supporting Command Center

Following are the stakeholders that will be using or supporting the functionality of the command center.

1. Calling executives – Folks answering the calls at call center
2. Data custodians – For ensuring data completeness, accuracy, authenticity
3. Triaging experts – Analyzing patient request and routing it to right people
4. Care coordinator – Responsible for end-to-end patient care. Patient concierge
5. Nurses – Nursing staff to care for patients – on site and remotely. Can function as doctors' assistants in terms of responding to patients.
6. Attending doctor – Care administrating doctor on site.
7. Physicians
8. Oncologists
9. Radiologists
10. Pathologist
11. Procurement and logistics
12. Documentation experts
13. Training experts
14. Facilities administrators
15. Third party representatives (hospitals, labs, govt, NGO, Transport for material movement, etc.)

3.5.4. Data Interfaces with Internal / Third Party Systems

1. Patient clinical data – EMR, radiology images, path lab report, patient reported outcome, patient generated data (home care data, uploaded images, etc.), clinician notes, etc.
2. Patient schedule and care coordination data (including payment and insurance information)
3. Patient services information – schedule of services, material needed (physical – samples collection, nutrition etc., virtual - education material, etc.)
4. Care coordination team: Care team that is working with each patient and their overall and current responsibilities
5. Material supply chain data: Stock, ordering information, etc.

4. Execution Framework

4.1. Formation of Karkinos Healthcare

To improve the efficiency of cancer care one must look across the entire cancer care pathway and move away from a fragmented care approach to an integrated care approach. An effective response to cancer requires strengthening all health system functions along the entire, care-control continuum - primary and secondary prevention, diagnosis, treatment, and palliative and survivorship care.

Karkinos Healthcare Private Limited is built with an aim to provide an end-to-end oncology focused managed technology platform where almost no person is deprived of care either by lack of access or affordability. The idea is to deliver care on the back of a technology-enabled oncology platform, providing decentralized cancer care, decoupling knowledge systems from delivery.

In line with the developed framework for technology in section 3.4, Karkinos technology platform consists of a distributed architecture with the development of tools/applications that will integrate seamlessly and

securely to a Karkinos backbone in discovery, diagnostics and treatment strategies. This will nurture innovation and newer therapeutic approaches to improve outcomes, in addition to becoming a strong revenue generator. The clinical data repository, curated knowledge base and advanced analytics will be part of the Karkinos offerings.

Karkinos Healthcare was founded by the author of this Innovation Report. Karkinos is supported by an eclectic Founding Team with strong technology, healthcare and finance experience, and a panel of eminent clinical and scientific advisors both in India and abroad. The team in their earlier avatars have built close to 20 cancer centres in the last decade. The company also has several professionals of eminence in cancer care as part of its Global Scientific Advisory Board.

The vision of Karkinos powered by the 4Ds

- Detection & Diagnosis - Establishment of participatory systems and near home care, Research on genomics as a foundational approach for prevention, Innovation and game-based outreach approach for early diagnosis and wellness
- Delivery of managed health care - 2 million+ patients served annually, 10 million+ patient hours saved annually
- Data platform providing Knowledge, Insights & Research - Contribute towards Atmanirbhar Bharat through drug discovery research and treatment innovation, Large scale screening and longitudinal data to build robust AI/ML analytics, predictive models and clinical decision support system for real world evidence

Key enablers

- Digital - All Karkinos services including patient registration, billing, patient navigation, screening, lab services, consultation, reporting etc., will be digital

- Remote - Karkinos services will use a nurse-led model, where doctor consultations will be provided using tele-consultation, with in-person consultation on pre-arranged dates.
- Cashless - The world has turned digital, with rapid adoption of digital payments. All Karkinos payments will be captured using Point of sales (POS) machines, UPI or other forms of digital payments. Patients will be advised and guided to make payments digitally in place of cash.
- Presenceless - The availability and accessibility of services for care seekers is important. Karkinos services are supported by a technology driven, oncology focused managed health care platform, providing seamless tele-health services, without the need for traditional health care clinical settings.
- Paperless - Karkinos services are eco-friendly and will use digital technology to save paper. All Karkinos reports will be provided in a digital format, unless requested by a patient or citizen visiting our clinic.

Karkinos Operating Framework

KH aims to significantly enhance access to cancer care services by creating a technology-enabled data driven platform and DCCM, wherein the knowledge architecture is centralized, and the delivery systems are democratised and distributed.

The DCCM encompasses a 'hub-and-spoke and further spoke' hospital infrastructure on the back of a robust technology and clinical decision support systems, that enables service delivery in a wide patient catchment. The network, whose geographic distribution will increase accessibility and reduce families' unproductive days, is designed to be 'wired' in order to enable connectivity amongst all centres. The central hub will provide staff training; seamless access to data and diagnostics; and a central knowledge repository and diagnostic capabilities.

A technology-enabled oncology platform, whose design and delivery will be through bespoke solutions for cancer care – A one-stop patient centric oncology platform bringing improved nation-wide cancer care to patients using a data driven distributed cancer care ecosystem comprised of doctors, clinics, hospitals, and digital mediums. It will use technology and AI based continuous feedback to improvise care to patient need, the learnings of which would be scaled up within India and beyond.

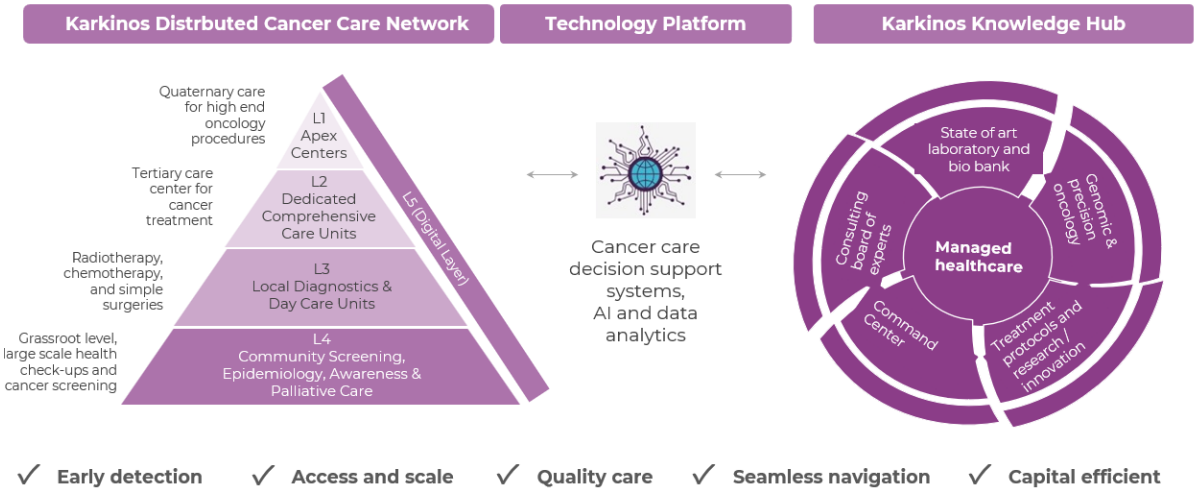


Figure 10: DCCM with technology-enabled oncology platform

Source: Karkinos

The model leverages a technology backbone that links anchor referral hospital/s that cater to complex cases, surgery, and radiotherapy with a network of smaller centres for diagnosis and ongoing treatment. This will help in decentralising the treatment thereby, reducing the load on Apex centres for non-complex treatment while increasing accessibility and cutting down on loss of productive days for the family.

From a patient perspective, we expect this to lead to earlier cancer detection, improved treatments, locally available medical care, significantly lower costs, and a better cancer-care experience.

Karkinos identified the state of Kerala to pilot the DCCM as the state has one of the best health indices in the nation in education and health care and is on par with those of developed nations. Kerala also reports about 58% more cancer incidences than the national average. In addition, the lifestyle

deviations suggest the burden in terms of somatic mutations loom large given the increased obesity cases, high tobacco and alcohol consumption, etc.

We piloted the technology-enabled distributed cancer care model (DCCM) in two districts of Kerala using a managed health care architecture.

4.2. Cancer incidence in Kerala

Kerala, a state with a population of 33 million, has 21 cancer-treatment facilities. As of 2018, these facilities were the resources available to an estimated 200,000 cancer patients in the state, and new cancer diagnoses numbered 135.3 per 100 000 people—the highest in the country—totaling 44,650 new cancer patients per year (Kerala Health Statistics). The situation is progressively getting worse, with cancer causing a healthcare crisis (Javakrishnan, 2020).

In this 50% of cancers are in the throat, mouth and lungs in male and 15% in women caused by tobacco and alcohol habits. Overall tobacco is responsible for 50% and diet for 10-20% of cancers. Breast cancer is the most common malignancy among the women in Kerala; about 30 to 35% is accounted by breast cancer (Kerala Health Statistics).

While there are higher number of cancer cases and associated high mortality rates, Kerala has a robust health system across public and private sectors with 1,281 allopathic institutions and ~99,000 beds spread across the state. However, this health system is divided with convoluted cancer care diagnostic and delivery structures (Javakrishnan, 2020). This fragmentation and siloed care delivery results in late-stage diagnosis, delayed treatment, inequitable cancer care and higher cost to patients. 42% of Kerala population pay for treatment through out-of-pocket expenses. This creates emotional and financial burden on the individual and family.

A study by World Health Organisation (WHO) showed that despite substantial investments made in improving diagnostic and treatment capacity for cancer across Regional Cancer Centre (RCC), Malabar Cancer

Centre (MCC) and five government medical colleges, there are districts such as Idukki, Wayanad, Palakkad and Kasaragod where access to cancer care facilities are virtually absent.

4.3. Distributed Cancer Care Model for Kerala

The DCCM will keep patient at the heart of the change and use technology to provide a seamless and decentralised care to citizens. This model will strengthen public-private partnerships and with direct investments made in areas where there is substantial lack of infrastructure and human resources for cancer care.

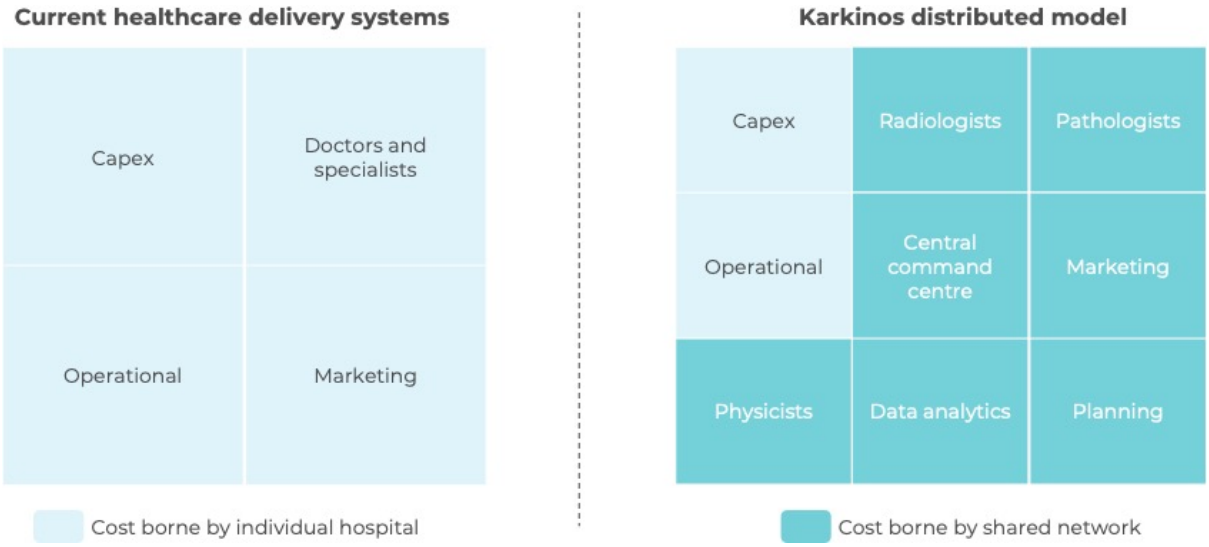


Figure 11: Cost reduction advantage with a shared knowledge network

Source: Karkinos

4.3.1. A participatory model providing distributed cancer care

A participatory model rather than a traditional proprietary model of cancer care will effectively utilise the available human resources and utilities spread within and outside Kerala to provide equitable care. The Distributed Cancer Care Model (DCCM) addresses the common risks of quality and poor coordination that come with a decentralised model through use of technology and a patient first ethos and mindset. The technology and knowledge driven architecture will enable patients to have a standard

experience across all centres, get diagnosed early and referred to the right centre for continued treatment.

The proposed DCCM segments cancer care across five levels to create uniform patient experiences across the ecosystem

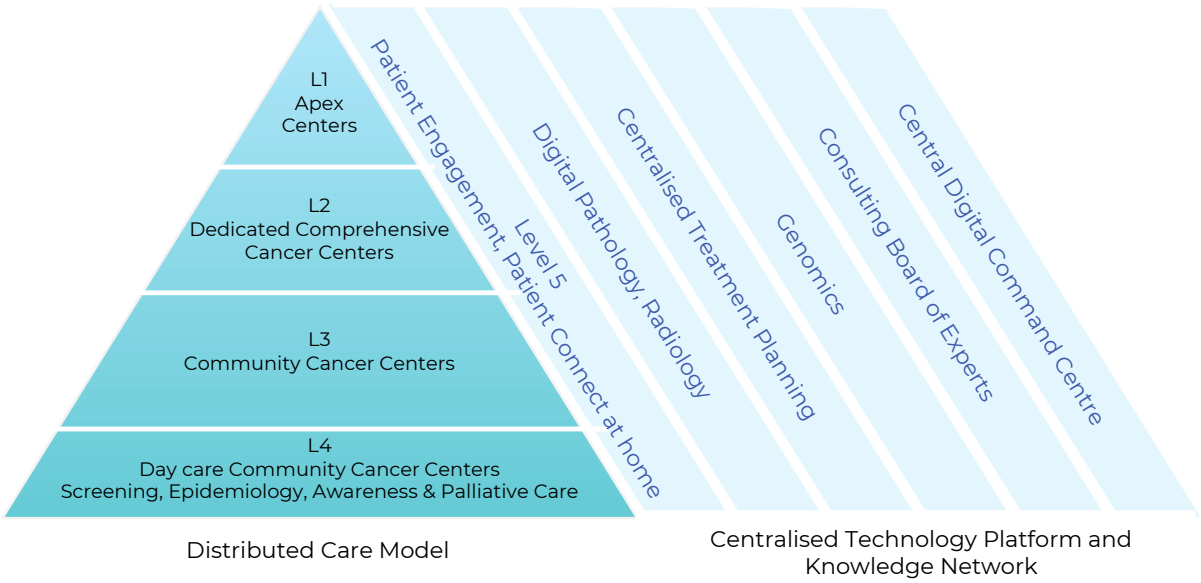


Figure 12: DCCM with an augmented intelligence architecture

Source: Karkinos

Level 5 (L5) is the digital layer, where patient engagement and connect can happen through commonly available smart devices. Citizens who have probable symptoms of cancer can complete pre-screening using a mobile application to receive further guidance to visit the nearest screening and diagnosis facility. The L5 layer connects togethers all the layers of DCCM. All appointments will be facilitated through digital mediums or a virtual command centre. The patient's requirement and considered clinical opinion will determine where the patient will be referred for further staging and treatment.

Level 4 (L4) is the early diagnosis facility to confirm or rule out disease and give them a good healthy life, and offers community screening, epidemiology, awareness and palliative care. Essentially, the L4 centres will be equivalent to primary health centres along with kiosks functioning in medical colleges or private hospitals, where people can walk in or referred

through digital initiatives. The screening criteria will use assessment (AX) cut off points for each cancer type to provide services.

L4 centres will help not only detect early disease but also introduce palliative care to address one of the major ethical issues in detecting early a number of advance cancer cases where treatment is unlikely to cure patients.

DCCM will bring in a balanced evidence-based approach to treatment and follow up care by centralising services such as histopathology, radiology, medical prognosis, treatment and orchestration of care, while ensuring the interventions across all the services are quality assured and the patient has the best outcome in terms of long-term survival and quality of life.

Level 3 (L3) centres will provide diagnosis and day care services for common forms of cancer such as oral, breast, head and neck, cervical, colorectal and lung cancers. These cancers will be gradually extended to other forms of cancer. At L3 centres, a patient is provided with digital diagnosis services to arrive at a reasonable conclusion for prognosis and any further treatment. It is imperative that patients receive a clinical examination by a skilled medical practitioner as the first point of diagnosis before subjected to invasive diagnosis methods.

Telepathology and teleradiology services can be made available across all DCCM centres, while managed through a virtual command centre and established partnerships with medical equipment manufacturers. Through use of digital solutions, citizens in Kerala will gain access to world renowned oncology specialists across India and the world and receive advisory and treatment support through video consultations, virtual tumour board, tailored treatment plans among others.

Level 2 (L2) will be dedicated comprehensive care units which handle less complex cancer cases which have been staged and focus on frequent diagnostic and therapeutic procedures. In Ernakulum and Idukki districts in Kerala, there are general hospitals, which are equivalent to L2 centre. The Idukki centre is not well equipped and is trying to develop a medical college, but there are private hospitals available which are well equipped. In Idukki

and Ernakulum, there are some mission hospitals which can be utilised and in areas where there is a lacuna, additional resources will need to be invested along with usage of public-private partnerships.

Level 1 (L1) are apex centres which are well recognised or established centres providing a range of cancer care services including complex treatments. There are existing hospitals such as the Regional Cancer Care (RCC) Centre, Thiruvananthapuram, Cochin Cancer Research Centre, Kochi and Aster Medcity Hospitals among others. For institutions that would deploy DCCM, it will be easy to work with these apex centres through memorandum of understanding (MoU), and make long terms plans to set up an own apex centre based on need, to provide cancer care support.

4.3.2. Institutionalising care with building blocks for DCCM

The DCCM will be ethical with careful consideration for legal and medical processes leading to creation of a large database to improve patient outcomes. The building blocks for Kerala are envisaged to be participatory in nature in order to help establish relationships with existing medical providers and invest in areas where there is a lacuna of infrastructure and human resources for cancer health services. The building blocks are designed keeping patient at the centre with focus on key stages of prevention, diagnosis, treatment, surviving, monitoring and end of life care.

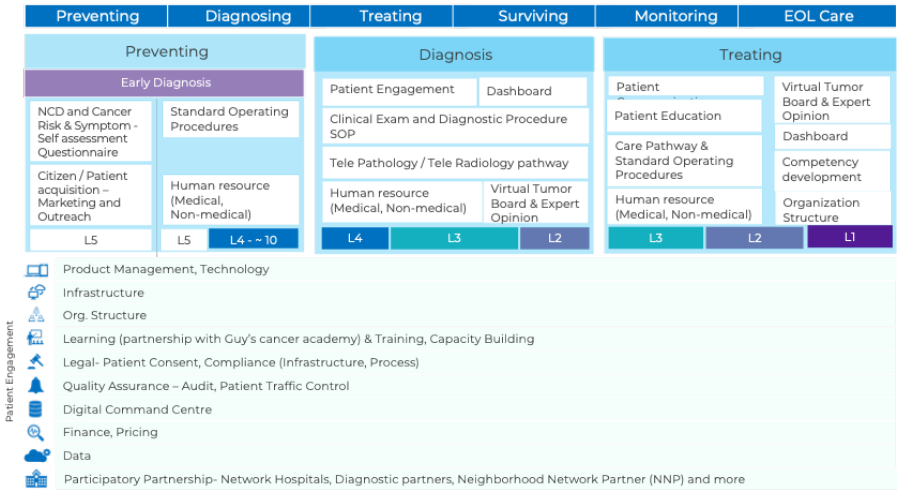


Figure 13: Key Building blocks (sample) to enable DCCM

Source: Karkinos

4.3.3. Establishing a gold standard for learning and creating competent workforce

The right counselling is another key part of cancer care to alleviate the mental and emotional strain and improve quality of life. Another key component is to have competent care providers who are trained at the L4 centres and reorienting oncologists and patients working in L3 and L2 centres. For example, if a patient comes with a breast lump, the trained physicians will be able to examine and provide right counsel to women about the condition and guide repeat examinations.

4.3.4. Enabling equitable care with mix of partnerships, government schemes and funding mechanisms

There are different socio-economic categories which causes a major limitation to finance health care. With information on all available forms of health care support including CGHS facilities provided by the Kerala government, particularly for the socioeconomic and downtrodden population it is possible to provide appropriate advice so that their diagnosis and treatment can be made feasible and affordable with treating institutions receiving appropriate reimbursement. Hence, there will be equitable care provided for people across all walks of life.

As more patients are treated through DCCM within Kerala, the insurance partners along with reinsurer can utilise data for offering affordable solutions that meet needs and become a market differentiator and be a profitable sustainable offering for insurers.

4.3.5. Command Center

Command center will support process workflows for various patient services offered across various centers. The command center will be the first interaction for all the patients. The information needed for the KH experts for supporting the patients across various sites (analysis, navigation, concierge, etc.) will be available on the dashboards in the command center.

The workflow support will be provided and tracked for each patient and each service request.

Command center is the centralized knowledge network across multiple hospitals which supports process workflows for various patient services. It is the central pillar coordinating and orchestrating every step of the care that includes scheduling appointments, reminding the team, distributing patient reports, notifying the right people about the next steps, documenting adequate data and ensuring the accuracy of the patient data recorded at every step of the journey. It is the backbone of patient navigation that enables smooth, transparent communication as well as maintain the human element that is based on personal comfort and empathy.

4.3.6. Using technology and genomics to find continuous ways to improve quality of life

The management and security of patient data records and security is another key building block for execution. The right management of data records can help provide timely care making it easy for medical doctors to view and decide on right treatment procedures. With advances in technology, and availability of data records in private clouds, the traditional challenges in securing patient data can be overcome. With a cloud architecture, the data can be securely accessed at any location using a connected network. The secure data records will aid in engaging patients in participative decision-making during cancer treatments. There is an increased understanding about the importance of involving cancer patients in decision-making about their care, with the literature identifying an association between participation in decision-making by patients and their families and improved patient satisfaction and quality of life.

The data collected will also be the key driver of understanding specific genomic profiles of tumours with the clinical annotation that will aid in drug discovery, diagnostics and treatment strategies. This will nurture innovation and newer therapeutic approaches to improve outcomes. In addition, this is

expected to be a strong revenue generator. The clinical data repository, curated knowledge base and advance analytics will be used by the technology platform.

5. Implementation Approach and Learnings

A hub-and-spoke with further spoke model in Kerala with a pilot in two districts – Ernakulam and Idukki, was identified to provide the implementation approach to reduce delays in diagnosis and treatment, standardise treatment protocols, provide equitable treatment and regular follow-up.

5.1. Objective

Developing an implementation framework for delivering cancer care services using a hub-and-spoke and further spoke model driven by technology.

5.2. Methodological Approach

In line with the objective, we employed an action research approach. This is a set of actions around key elements of collaboration with the partner organisations to promote action and change.

5.2.1. Action Research Approach

Action research is an emergent process which evolves as understanding increases and an iterative process which leads towards a better understanding of the area under investigation. Action research uses mainly qualitative methods because it is concerned with participants' meanings and understanding. It is usually participative since change is more easily achieved when those affected are involved in the process. Action research has gained acceptance as a method for testing ideas in a real-world setting. When doing action research, interpretive action research, also known as "modern action research," sees business reality as socially created and focuses on local and organizational variables (Cardno, 2003).

Action research entails taking action, evaluating, and critically analysing practices based on data acquired in order to improve relevant activities. This form of research is made possible by the participation and collaboration of a large number of people who have a same goal. This type of study concentrates on unique circumstances and their context.

To build the framework of action research for distributed cancer care network, the first step is to identify the right partners organisation and levels of engagement.

5.2.2. Selection of partner organisation (hub and the spokes) and the key elements for engagement

An understanding of the partner organisation history, location, community engagement, services, and organisation ethos is essential prior to selection and initial conversation. When looking for the right partner organisation, the following broad criterias are considered for selection:

The partner organisation is

- a well-established hospital offering comprehensive diagnosis, radiology and laboratory services
- keen to set up oncology services
- willing to partner and support deployment of early detection services, as well as commit to the aim of reducing the burden of cancer
- having existing community outreach health programmes and has a strong reputation within the community
- committed to investing resources, time, and lending support to jointly set up cancer care services

After selection, the key elements for engagement with the partner organisation includes mainly the following:

5.2.2.1. Governance

- The cancer centre will operate as a single service line for all oncology-based activities including community and outpatient screening, diagnostics, day-care and in-patient treatments (including, but not limited to early detection, palliative care and day care chemotherapy)
- Karkinos will manage and carry out the day to day running of the Oncology Unit at the Hospital premises

5.2.2.2. Technology

- The partner organisation will make necessary provisions to enable Karkinos set up a separate Hospital Information System (HIS) to run the Oncology Unit operations
- All matters related to cancer care cross the patient continuum (diagnosis, surgery, chemotherapy, radiotherapy and supportive care) will be under one common umbrella of Karkinos in order to ensure a seamless patient experience

5.2.2.3. Infrastructure

- Karkinos will set up and develop the 'Karkinos Cancer Centre' / 'Oncology Unit' at the earmarked premises to offer oncology related services
- Karkinos will undertake modifications to the existing infrastructure, setting-up of IT services, furnishing, equipping, setting-up day-care chemotherapy, oncology pharmacy, oncology laboratory and any additional radiology equipment that may be required to establish the Oncology Unit

5.2.2.4. Clinical Services

- Karkinos will recruit and provide training to qualified medical, para-medical and administrative staff for the cancer care services. Where possible, Karkinos will leverage and train existing staff from the partner organisation

- Partner Organisation will make available its hospital services including, not limited to, laboratory services for patients undergoing screening and treatment at the Cancer Centre
- Partner Organisation will make available the support of required doctors subject to availability for the oncology unit
- Karkinos shall work with the partner to create and manage the medical and non-medical standard operating procedures for the cancer care services, with guidance from representatives of partner organisation
- Karkinos shall establish prices, rates and charges for the services provided at the Oncology Unit

5.2.2.5. Community Engagement Programmes

- Partner organisation shall undertake awareness programs and promotion of the Oncology Unit and the medical services offered
- Partner organisation shall support the community cancer clinic for early detection programmes, partnering with like-minded organisations

5.2.2.6. Finances

- Karkinos would bear all costs and liabilities associated with the operations, management and administration of the Oncology Unit including equipping and staffing the Oncology Unit
- Any billing to be done by the Oncology Unit shall be in the name of the Oncology Unit and such bills would be raised by Karkinos for and on behalf of the Oncology Unit
- For referral services, Karkinos shall formulate a suitable percentage revenue share model with the partner organisation

5.2.3. Community Cancer Clinics (further spokes)

Screening programmes apply the most focused and sometimes resource-intensive, early detection strategies in which patients are tested for cancer before symptoms are apparent or pronounced. Early detection programmes use public health instruments to identify individuals with cancer before their disease develops into advanced stage cancer at which time successful treatment can become difficult or sometimes impossible.

We focus on early detection and screening methods of six common cancers viz. oral, breast, cervix, colorectal, lung, prostate.

A pilot early detection and screening programme in Kerala is currently underway with Chazhikatttu Multi-Speciality Hospital in Todhupuzha, Idukki District, as the pilot centre.

The criteria for an effective screening programme for Karkinos Healthcare are:

- an explicit policy, with specified age categories, method and interval for screening
- a defined target population
- a management team responsible for implementation
- a clinical team for decisions and care
- a quality assurance structure with links to information systems for patient follow-up, monitoring and evaluation

5.2.4. Cancer Screening Approach and Methods

Karkinos cancer screening pathway is derived from WHO guidelines on cancer screening which involves the following broad steps (WHO, 2022) –

1. Systematic invitation
2. Application of a screening test
3. Diagnostic evaluation

4. Treatment

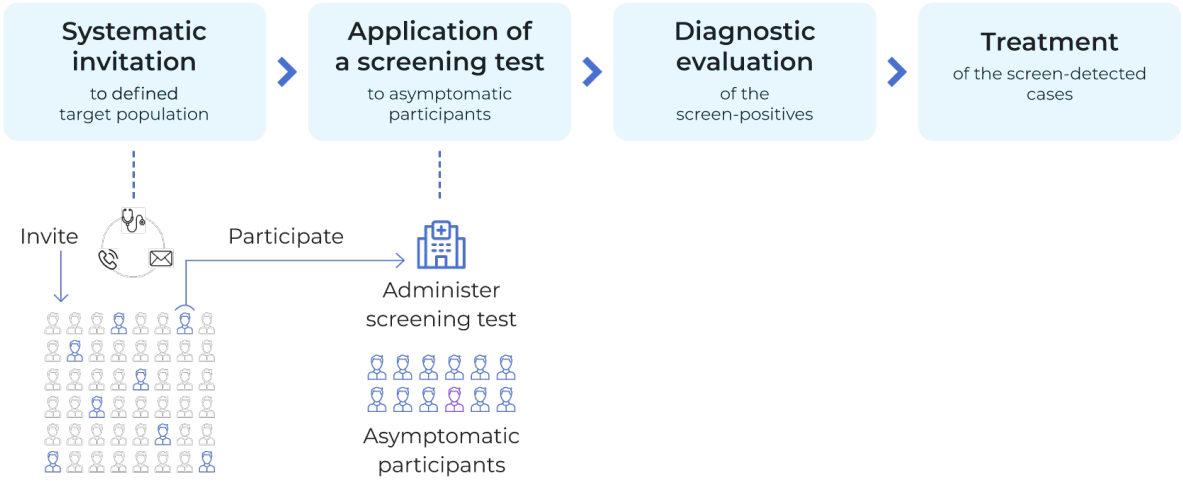


Fig: Screening Pathway

1. **Systematic Invitation for risk assessment followed by screening test at the community camps**

For systematic invitation to a defined population, here again, the first step is to identify the right partners organisation.

Selection of partner organisation

An understanding of the community partner organisation community engagement, services, and organisation ethos is essential prior to selection and initial conversation. When looking for the right partner organisation, the following criteria are considered for selection:

The partner organization is -

- having existing community networks and has a strong reputation within the community
- An established organization offering societal value
- keen on taking oncology services to the people
- willing to partner and support deployment of early detection services, as well as commit to the aim of reducing the burden of cancer
- committed to investing resources, time, and lending support to jointly set up cancer care services

Systematic invitation steps

Step 1: Mapping of the community catchment, population spread, population segment.

Step 2: Finalise dates for screening camp and the dates for pre-screening activities such as awareness, promotion, recce, facility readiness and identification of community volunteers for mobilisation and facilitation.

Also ensure closure on payment modes for the population and funding support for screened positives for further investigations at the Karkinos clinical facility.

Step 3: Complete the facility assessment checklist and take the sign-off from the stakeholders viz., Karkinos clinical team, outreach coordinator and partner organisation designated in-charge.

Step 4: Inauguration of the population-based cancer screening programme followed by cancer awareness session by Karkinos Medical Expert.

Step 5: Cancer risk assessment questionnaire (provided in annexure 2) administration for the eligible population, followed by oral visual examination for men and women, and clinical breast examination for women.

Step 6: Follow-up care coordination of high-risk population / screened positives - A well-organized programme should ensure access to confirmatory diagnosis and to treatment if precancer or cancer is suspected/diagnosed. The suspected individual from the camps are followed up via a “phygital” construct, which includes ground- level as well as a virtual command centre follow-up.

2. Screening test at a Karkinos-partnered healthcare facility

This involves a comprehensive check-up for all or specific cancers under the direct supervision of a Karkinos trained physician. The command centre and ground staff follows up with the screened positive or high-risk patients for

the comprehensive check-up. The healthcare facility may also receive direct walk-ins.

We are screening individuals in a specified age category, defined in the table below. The screening criteria has been develop by Karkinos Medical Team based on already existing national (Indian Council of Medical Research and National Cancer Grid) and international guidelines (American Cancer Society, World Health Organisation and National Comprehensive Care Network).

Site	Age/Eligibility	Screening modality	Screen positive	Screen negative
Breast	Asymptomatic: 30-74 years	• Awareness with periodic breast self-examination • Screening clinical breast examination	• Bilateral Mammogram and / or USG • If mammogram positive: refer for histological confirmation	Repeat screening • Every 1 year (>50 years) • Every 2 year (<50 years)
	High risk of breast cancer: age not a criterion	• Awareness with periodic breast self-examination • Screening clinical breast examination • Bilateral Mammogram and / or USG	Refer for histological confirmation	Repeat screening • Every year
Cervix	30-65 years	• HPV test • Visual Inspection using Acetic Acid (VIA) / PAP as an alternate screening method in a resource-constraint settings/ government setting as applicable	Triage with Colposcopy and further management according to protocol.	• Repeat PAP in 3 years • Repeat HPV in 5 years. • Health education on hygiene and symptoms
Oral	30-74 years with risk factors /symptoms	COE (Clinical Oral Examination)	• High risk/suspicious lesion: Refer for histological confirmation • Low risk lesion: Observe: Follow up 3-6 monthly interval, patient education	• Repeat screening once in three years • Patient education

Colon	45-74 years	FIT	• Colonoscopy: if positive Refer for histological confirmation • Colonoscopy negative: repeat FIT in 3-6 months.	• Repeat screening every year. • Patient education
	Symptomatic patients/ High risk	FIT	• Colonoscopy: if positive Refer for histological confirmation • Colonoscopy negative: repeat FIT in 3-6 months.	• Repeat screening every year. • Patient education
Prostate	Above 40 -49 Above 50	Risk Assessment	• If symptomatic – advice PSA • PSA	• Repeat screening every year
Lung Cancer	High Risk (>40 years, cig >20 packs) Low risk (<40 years, cig <20 pack years)	Risk Assessment	• Low Dose CT • Smoking cessation	• Repeat after 1 year

3. Diagnostic Evaluation of screened positives / cancer patients:

Using Karkinos protocol for cancer clinical management the physician and/or oncologist at the partner healthcare facility guides the patients for further investigation and care. The facility may also receive walk-in cancer patients.

4. Treatment

Treatment modalities, at the pilot hospital ie. Chazhikattu Hospital, includes chemotherapy and surgery. Radiation Therapy if required is done at the next Karkinos-partnered referral centre – Rajagiri Hospital, Aluwa, Ernakulam.

The diagnostic and treatment pathway are discussed and decided by a panel of Oncologists at Karkinos connected via the Virtual Command Center (VTB).

The treatment protocols for patients under Karkinos care are derived from the standardized care plan library curated by Karkinos based on activities, rules and workflows from the Standardized Guidelines of Care from various sources, e.g., National Cancer Grid (NCG), National Comprehensive Cancer Network (NCCN), American Society of Clinical Oncology (ASCO), among others. The figure below is an illustrative clinical guidelines and pathways for lung cancers.

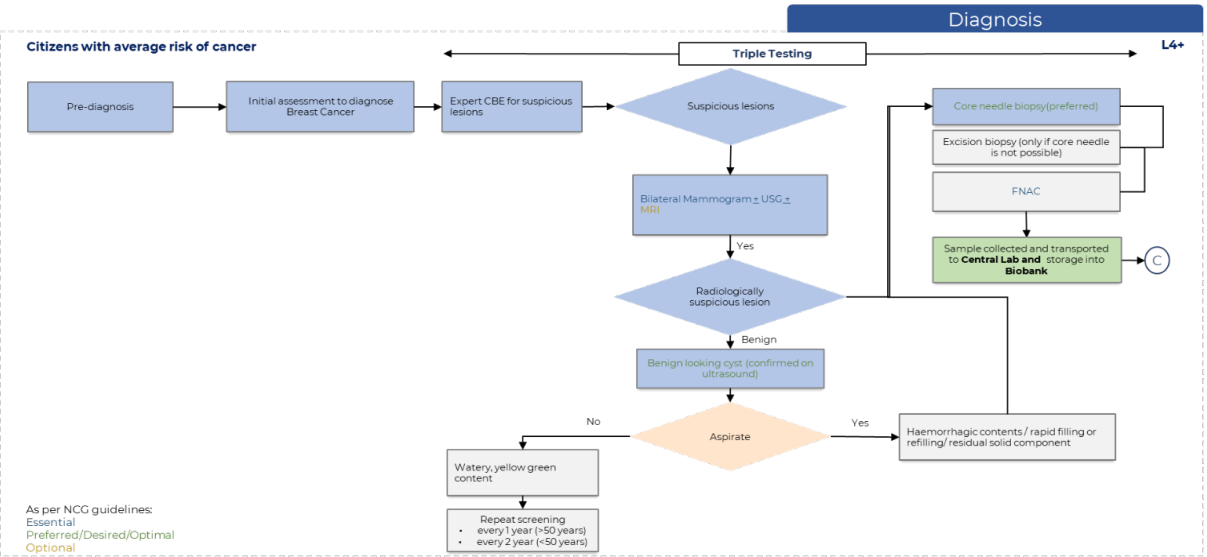


Figure 14: Illustrative clinical guidelines and pathways for lung cancers

Source: Karkinos

5.3. Results - Karkinos Cancer Centers (the hub-and-spokes)

The pilot execution is at its first phase of implementation in two districts of Kerala – Ernakulam and Idukki. Partnership will different types of hospital are at various stages of progress. Eight hospitals have signed an agreement to facilitate the implementation of DCCM – each hospital offering different level of cancer care services depending on the population catchment demand and density, diagnostic and treatment capabilities and ancillary supports.

The model has received a support from the Government of Kerala and has commissioned a large building space in a prime location in Kochi to

operationalise the central lab and command center for advanced pathological diagnosis and patient care coordination, respectively.

Karkinos has received a formal approval from the Central Drugs Standard Control Organisation (CDSCO), India's national regulatory body for pharmaceuticals and medical devices, under the Directorate General of Health Services, Ministry of Health & Family Welfare, Government of India, to form an Independent Ethics Committee to oversee research initiatives and monitor observational, translation and scientific research at Karkinos.

The pilot execution is at its first phase of implementation in two districts of Kerala – Ernakulam and Idukki. The Karkinos Cancer Center in Chazhikattu Multi-Speciality (CMS) Hospital in Idukki District (an L3 center) was launched in July 20, 2021. All the cancer treatments were performed outside the Idduki district before the Karkinos Cancer Center was established in Idukki district.

Karkinos launched its first L3 partnership with Chazhikattu Hospital in Idukki District in July 20, 2021. 1000+ individuals have been screened for cancer and out of which 33 people have been detected with early signs of cancer, who are being regularly followed-up and ensured a proper care continuum by dedicated care coordinators at the command center. None have advanced to the treatment phase. The center has also seen 30+ cancer patients. The first chemotherapy was administered on August 6, 2021, and so far, 55 chemotherapies have been administered. The first cancer surgery was performed on Aug 7, 2021.

For regular radiology and pathology tests, the patient care is provided in the same hospital but for staging purposes, which in some patients requires a PET CT to be done, the patients are referred to the nearest L2 which is Rajagiri Hospital, with whom an agreement was signed about a month back. Between these two centers, the attempt is to ensure a seamless patient experience in terms of the same care coordinator ensuring navigation, one-stop payment system at Karkinos, standardized pricing, and quality of care, driven by technology, thus enabling a distributed cancer care network for cancer care.

One referral center (hub) and five pilot centres (spokes) were onboarded sequentially between July 2021 to September 2021, with interventions at different stages advancement. Figure 19 lists current partnerships, which were established through a selection criteria.

	Community Engagement	Early Detection and Wellness	Diagnosis	Treatment (Chemo)	Treatment (Radiation Oncology)	Treatment (Surgical Oncology)
CMS Hospital, Idukki	✓	✓	✓	✓		✓
Munnar Tata Hospital, Idukki	✓	✓	✓	✓		
Mar Besilios Medical Mission Hospital, Ernakulam	✓	✓	✓	✓		
SD Tata Hospital, Ernakulam	✓	✓				
Peace Valley Hospital, Ernakulam	✓			✓		

Figure 15: List of partnerships and oncology services offered

Figure 20 below highlights the progress made in one quarter.

Services	Community-level Screening	Comprehensive Wellness Screening	Diagnosis	Treatment (Chemo)	Treatment (Radiation Oncology)	Treatment (Surgical Oncology)
CMS Hospital, Idukki	1000+	400+	100+	50+	X	4
Munnar Tata Hospital, Idukki	100+	0	30+	10	X	X
Mar Besilios Medical Mission Hospital, Ernakulam	200+	150+	50+	5	X	X
SD Tata Hospital, Ernakulam	0	70+	50+	0	X	X
Peace Valley Hospital, Ernakulam	X	X	X	35+	X	X

X – not applicable

Figure 16: Oncology services in the five centres (spoke) and summary of the progress.

5.3.1. Cancer Centre 1 – Chazhikattu Multi-Speciality Hospital

Service Launch

The centre was launched on July 20, 2021. The management is supportive of setting up oncology services and aspires to become a comprehensive cancer care centre in the near future. While the management is supportive, more awareness and communication among the doctors and the cancer centre required. The cancer centre operates as a single service line for all oncology-based activities.

Community engagement

Community engagement programmes initiated in several locations with different target segments.

Technology

The HIS of the hospital is in the process of upgradation hence the integration with Karkinos IT system is pending. Currently, the process for using the lab and radiology services are manual. A paper printed requisition form is carried by the patients to the respective hospital departments. The patient records and summaries are shared digitally between Karkinos and the hospital.

5.3.2. Cancer Centre 2 – Mar Besilios Medical Memorial Hospital

Service Launch

The centre was launched on August 30, 2021. The management is supportive of setting up oncology services and is one of the first hospital partnerships.

Community engagement

The partner organisation has a nursing college and community partnerships, which were leveraged to provide awareness and conduct risk assessment screening services. A 15 day community engagement programme with the local panchayats (village councils) covering 31 wards is initiated.

Technology

A basic HIS of the hospital exists and is integrated with Karkinos IT system. A paper printed requisition form is carried by the patients to the respective hospital departments. The patient records and summaries are shared digitally between Karkinos and the hospital.

5.3.3. Cancer Centre 3 – Sir Dorabji Tata Hospital

Service Launch

The centre was launched on September 15, 2021. The management is supportive of setting up oncology services and is one of the key partnerships.

Community engagement

The partner organisation has strong cultural and community partnerships, which were leveraged to provide awareness and conduct risk assessment screening services. Patient awareness sessions with education institutions, cultural centres and communities are underway.

Technology

No HIS exists and the services are run using the Karkinos IT system. The patient records and summaries are shared digitally between Karkinos and the hospital.

5.3.4. Cancer Centre 4 – Munnar Tata Hospital

Service Launch

The service at the centre commenced from September 12, 2021. A formal launch is planned in December 2021. The management is keen to set up the oncology services and is a key partnership to cover Munnar and Idukki district, where are currently no cancer facilities.

Community engagement

The partner organisation serves employees across nine estates, who are tea plantation workers and cardamom farmers. Several community risk assessment screening programmes are underway in the estates

Technology

A basic HIS of the hospital exists and the integration with Karkinos IT system is planned. The patient records and summaries are to be shared digitally between Karkinos and the hospital.

5.3.5. Cancer Centre 5 – Peace Valley Hospital

Service Launch

The day care services was launched in June 2, 2021 to cover the Kothamangalam and nearby areas.

Community engagement

The partner organisation has strong community and palliative network, which is leveraged to promote chemotherapy services. During the Covid period, a helpline was opened to promote cancer awareness and provide near home chemotherapy.

Technology

No HIS exists and the services are run using the Karkinos IT system. The patient records and summaries are shared digitally between Karkinos and the hospital.

Finance across the partner centres

Across each centres, the billing related to oncology services is at the Oncology unit. All referral services such as lab and radiology services etc. are billed and reconciled on a monthly basis without disrupting the patient experience.

Table 3: Partner hospital characteristics, implementation challenges identified and the proposed interventions.

Site	CMS	MBMMH	Munnar	SDTT	PV
District	Idukki	Ernakulam	Idukki	Ernakulam	Ernakulam
Location	Semi-urban	Semi-urban	Rural	Rural	Rural
Hospital type	Multi-specialit y	Multi-speciality	Multi-specialit y	Multi-speciality	Foundatio n
Daily average OPD footfall	1000	800	2000	250	100
Cancer care services in the region	X	X	X	X	X
Main issues identified					
HIS systems	Good	Poor	Moderat e	Poor	Poor
IT Integration	Pending	Not possible	Not possible	Not possible	Not possible

Management support	Good	Good	Good	Good	Good
Clinicians' support	Good	Moderate	Good	Minimal	Moderate
Inter-departmental communications	Moderate	Minimal	Minimal	Minimal	Minimal
Marketing activities	Moderate	Minimal	Good	Minimal	Minimal
Community engagement programmes	Very Good	Good	Very Good	Moderate	Moderate
Infrastructure	Very good	Good	Good	Moderate	Moderate
Main Interventions required					
Patient navigation system inside hospital	Y	Y	Y	Y	Y
Continuous education programmes	Y	Y	Y	Y	Y
Marketing and promotional activities	Y	Y	Y	Y	Y
Community engagement activities	Y	Y	Y	Y	Y

5.3.6. Referral Center – Rajagiri Hospital

The availability of high-end diagnostic equipment for confirmatory diagnosis and staging along with and treatment modalities such as Radiotherapy makes Rajagiri Hospital a referral center for the cancer centers. Located within the same or neighbouring district from the spokes, Rajagiri is looking at about 10 cancer patient required to undergo radiotherapy sessions.

5.4. Results – Community Cancer Clinics (spokes and further spokes)

Community Organisation Partnerships helped to take cancer care closer to homes. The programme made a huge impact since few health care services were being provided due to the COVID-19 restrictions and there were none for cancer. Even the regular camps by the Government Public Health Centers were non-functional in the times of COVID-19.

Some of the key partnership and the outputs are summarised below -

- Bus Operative Association

  Bus operative association is the association of private bus employees of Idukki district of Kerala. Karkinos has set up a kiosk for cancer risk assessment in the bus stand of Thodupuzha.

  In the first 45 days, 731 people registered and underwent risk assessment. 199 people were identified of high risk from the registered.
- Kerala Agriculture Development Society (KADS)

  KADS is a voluntary organization of farmers. Karkinos conducted cancer awareness session and screening for the first six wards of Thodupuzha municipality in the first week of November 2021. 35 people attended the awareness session and 24 people registered and undergwent cancer risk assessment. Out of which 10 are identified at high risk.
- Idukki Press Club

25 members attended the awareness session and 12 registered and undergone risk assessments, out of which 6 were identified of having high risk for cancer.

- Kalyan Silks

  Kalyan silks is the world's largest silk saree showroom network. Karkinos conducted cancer awareness class and cancer early detection programme in Kalyan Silks Showroom of Thodupuzha. 150 employees participated in the awareness session and 31 registered for risk assessment, out of which 10 were identified at high risk. 18 female employees underwent clinical breast examination.

- Pulimoottil Silks

  A famous textile outlet in the region. Around 100 employees participated in the awareness session and 69 registered for risk assessment. Out of which 10 were identified of having high risk for cancer. From the 69 clinical breast examinations, 2 were screened positive.

- Maharani Boutique

  One of the popular wedding boutiques in the region. Around 100 employees attended the awareness session and 60 registered and undergone risk assessment, out of which 21 were identified of having high risk of developing cancer. 3 were screened positive out of the 41 clinical breast examinations.

- Arakkuzha Grama Panchayat

  Arakkuzha Grama Panchayat is in the district of Ernakulam consisting of 13 wards. Karkinos conducted cancer awareness and early detection program at Arakkuzha Panchayat where about 80 people attended the awareness session, 31 registered for screening and underwent risk assessment, out of which 9 were identified of high risk. 2 were screened positive from the 31 clinical breast examinations done.

Overall with about 20 similar partnerships for the cancer community clinics around Cancer Center – 1, this pilot showed good response in terms of the

throughput, especially in the COVID-19 scenario, and feedback from the stakeholders, on the approach to provide an equitable cancer care in the region for early detection of cancers.

Summarily, the below are the numbers reached in the past quarter for awareness, screening further investigations and diagnosis.

Center	Community Awareness	Community level screenings	High-risk individual identified	Clinic visits for high-risk individuals	Diagnosis
CMS Hospital community catchment	1500+	1000+	280	30	10

The Karkinos central command center has supported process workflows for various patient services between the centers. It has ensured end-to-end patient navigation so that the patient drop offs are minimized ensuring patient compliance.

With the command center Karkinos been able to -

- Enable virtual care in all patient services to create scalability and accessibility of care to patients deprived of care
- Become single point of contact for patient to ensure that the patient has constant access to authentic information and guidance
- Ensure end to end patient navigation so that the patient drop offs are minimized ensuring patient compliance
- Streamline centralized care coordination to ensure the multidisciplinary aspects are considered
- Ensure data governance for completeness, accuracy to facilitate adequate, quality care for the patient with right information

An illustrative weekly reported data from the command center is presented below:

CC Call Data Dashboard		Week 46
In-bound calls	Service enquiries	33
	Other enquiries	3

Out-bound calls	FOBT follow-up calls	5
	OVE follow-up calls	10
	Referal hospital coordination	6
	Patient Appointments	3
	Service explanation calls	7
	Patient report communication	111
	Investigations follow-up calls	33
	Radiotherapy follow-up calls	7
	Tele consultation	3
	Screening camp calls(Follow up)	17
	Community Screening Appointments	1
	Calls not attended by patients	219

The key outcomes being -

- High quality, accessible care for Patient - no patient left behind
- Data as single source of truth - Lack of accurate and complete data causes challenges in patient care
- Improved stakeholder collaboration - multidisciplinary approach and close collaboration
- Optimized, automated care operations - efficiency improvement and taking human errors out will ensure care consistency
- Highly consistent, repeatable processes - repeatability across all locations and all stages to ensure consistency of care thus giving high quality care without errors

5.5. Recommendation of an implementation framework

There were variations among the participating partner organisations across the key collaboration elements. Each centre must locally adapt and

implement that best suits the local setting. The value proposition of setting up an oncology unit closer to homes in terms of bridging the accessibility gap in cancer must be understood. It must also be understood that prevention and early detection are the key for tackling the burden of cancer.

No one model for implementation works in the same manner for the different centres. Various implementation strategies may be particularly fitting and timely at different phases of the change process. To guide the selection of implementation strategies for a given implementation need, we propose an Implementation framework.

The framework begins with due diligence and engagement, moving to active implementation and monitoring, and then to evaluation and sustenance.

5.5.1. Due Diligence and Engagement

A	Assess geographic location for starting oncology services
B	Assess partner organisation interest
C	Assess infrastructure readiness
D	Identify barriers and facilitators
E	Develop the business plan with cost estimates and potential revenue streams
F	Develop stakeholders' relationship
G	Engage with clinicians early
H	Identify community influencers and early adopters
I	Develop team structures and responsibilities
J	Share knowledge base and protocol
K	Share company and staff credentials
L	Develop community engagement/ marketing strategy
M	Tech assessment and readiness - choosing the solution

5.5.2. Active Implementation and Monitoring

A	Publish and implement the care pathways across the departments
B	Develop synergies and relationship with the hospital staff for implementation of SOPs
C	Implement IT solutions and integrate with HIS integration
D	Adapt and tailor engagement plans
E	Adjust clinical and administrative workflows
F	Develop branding and communication material
G	Provide clinical supervision and technical assistance
H	Relook at the team structure and roles
I	Provide interactive assistance to the clinical team
J	Develop relationship with local like-minded organisations
K	Implement community engagement programmes
L	Review the business plan

5.5.3. Evaluation and Sustenance

A	Establish policies based on implementation learnings
B	Audit and feedback
C	Improve implementation fidelity
D	Establish performance metrics and incorporate into individual, team and organisational performance
E	Recognition and Rewards
F	Educational boosters and coaching

There is interplay between the strategies proposed for each stage such that components of active implementation, such as adjusting workflow or revising team structures, may occur alongside efforts on due diligence and engagement. Similarly, active implementation may also include strategies

that will ensure that established policies and engagements are supported and sustained.

Due Diligence and Engagement	Active Implementation and Monitoring	Evaluation and Sustenance
• Assess geographic location for starting oncology services • Assess partner organization interest • Assess infrastructure readiness • Identify barriers and facilitators • Develop stakeholders relationship • Engage with clinicians early • Identify community influencers and early adapters • Develop team structures and responsibilities • Share knowledge base and protocol • Share company and staff credentials • Develop community engagement/marketing strategy	• Publish and implement the care pathways across the departments • Develop synergies and relationship with the hospital staff for implementation of SOPs • Implement IT solutions and integrate with HIS integration • Adapt and tailor engagement plans • Adjust clinical and administration workflows • Develop branding and communication materials • Provide clinical supervision and technical assistance • Relook at the team structure and roles • Provide interactive assistance to the clinical team • Develop relationship with the local like-minded organization • Implement community engagement programmes • Review the business plan	• Establish policies based on implementation learnings • Audit and feedback • Improve implementation fidelity • Establish performance metrics and incorporate into individual, team and organisational performance • Recognition and reward • Educational boosters and coaching

Table 4: Summary of the action research approach framework.

Partnering with multiple organisations for a hub-and-spoke model of delivery of cancer care means adjusting and developing local solutions and strategies. While the partner organisation may aspire to have an oncology centre, it may not have the means to do so in the manner which Karkinos might be intending to. In such a setting, action research approach helps to guide implementation as it is active moment-to-moment theorizing, data collecting and inquiry occurring in the midst of emergent structure.

In order to make the distributed care successful, a robust network of governance that measures quadruple aim in healthcare is absolutely essential. Measuring the health outcomes, cost of care, patient and clinician satisfaction is necessary in order to ensure that the patient trust and seek care available to them close to home thus reducing burden on the apex center.

Care outcomes measurement metrics that includes the adherence to the defined, structured processes and workflows using the checklist, adherence to the evidence- based pathways ensuring effective patient navigation, effectiveness of each diagnostic and treatment procedures to cut down

unnecessary procedures avoiding additional cost and patient discomfort will be very effective.

Overall cost of care that includes the cost of running remote centers and ensuring right utilization of available resources will make the model viable beyond pilots. Patient and clinician satisfaction will ensure the human element and empathy in the system building on the pre-established trust framework within the community. Developing the effective measurement parameters for satisfaction every step of the way will also provide previously unknown insights and exposing hidden gaps in the care delivery. Addressing these gaps will ensure the longevity of the distributed care model paving the way of it becoming the standard of care for all chrome diseases in addition to cancer

5.5.4. Technology and Command Center

The distributed care with the hub – spoke and further spoke model is entirely possible by technology enablement and implementing lean and distributed command center.

The distributed care depends on the central knowledge repository and people at the remote location getting the access to the central repository and the personalized and case specific guidance for the patient care. The care delivery at the remote locations leveraging the central knowledge and guidance is made available by creating a technology platform that provides access to the knowledge, connects multiple stakeholders for defining the patient pathway and guide the care delivery personnel with the detailed process. The technology platform ensures that the patient history and other data is available at one place, that can be accessed by experts.

The expert guidance and automated guidance built in the system derived from the data assists the folks on the ground (who may not have the adequate skills) to take right diagnostic decision, define the care pathway and ensure that the best care of delivered. Enhancing on the automated clinical guidance, voice assistance based on the interaction with the ground

clinicians and other staff, simplifying the data gathering process, making the data exchange and insights available faster.

Following are the future improvement in the technology that will power the distributed care -

1. Voice assistance – stakeholders with voice assistance will make the user experience very seamless and intuitive. The conversation trees can be tailored to cancer, further customized to specific cancer types for precise support. The patients can have access to support at their fingertips throughout the care journey.

2. Mixed reality – training using mixed reality will help all stakeholders alike. The clinicians can get trained remotely from the experts in the fully immersive environment. The remote clinicians can have the advantage of training with the world expert for surgical procedures, screening, diagnosis, and treatment with remote access. The patients, caregivers can be trained remotely to perform a few tasks at home so that the patients get quality care at home.

3. Clinical guidance - The AI / machine learning will enable the expert guidance built in the platform that will enable downshift the skillset allowing hiring the local talent at the remote care center. Real time guidance embedded in the platform will provide assistance in usage as well as clinical guidance. Remote team can follow recommendations based on expert advice thus ensuring the patients get quality care regardless of the location.

4. Omnichannel communication automation – Care collaboration among care team taking care of the patients in person or remotely will be extremely seamless and effective if significant amount of the communication is automated and assisted. The clinicians will be able to get the updates about patient care and be able to provide right advice at the right time regardless of the location and channel of the

communication. Data exchange across various channel can also be streamlined.

6. Conclusion

6.1. Summary of Major Findings

Technology-driven solutions to bring healthcare closer to homes has been adopted in many countries, and in India, many public and private health care providers are heading toward similar delivery models. The importance of a coherent strategy for developing cancer centres for national cancer control by building on pre-existing recognised cancer centres that deliver care, training, and research to international standards is evident. Initiatives are being undertaken but many of these initiatives are currently fragmented and uncoordinated. The hub-and-spoke model has been receiving increasing attention of late as a potential solution to many population health challenges.

There is a lack of uniformity of care across the cancer continuum of care from prevention to early detection, evidence-based treatment and follow-up of cancer patients. This disparity has manifested primarily because of a lack of an established network of cancer centres across the country to implement common standard management guidelines. Though regional cancer centres exist in all parts of the country and geographically cover the population, they too have varying standards of care.

The hub spoke care model hinges on the standardization of care components that leverage centralized knowledge base. The centralized knowledge base in the form of standard procedures, workflows and care pathways makes it easier to create effective care centers that will provide evidence based, validated care. Taking care to patients home - it is evident and proven that the patient comfort and quality of life as well as recovery of the patient is far better if the patient receives care at home. It is imperative to look at each aspect of care continuum in an innovative way to identify as

many tasks as possible to move at patient home to provide quality care at home.

Hub-spoke and then further spoke needs to be extended to the edge upto the patient home. New technologies such as electrochemical, electromechanical nano sensors, new biomarkers in blood, digital pathology at point of care, hyperspectral analysis have opened new possibilites at the point of care to extend the care beyond vital parameter monitoring and tele consultation alone. Point of care diagnostic and treatment equipment at point of care are being productized. It is essential that the point of care solutions to incorporate these new technologies to advance care at the edge, even at the patient door step.

The key outcomes of the Karkinos DCCM based on the discussion with various health workers are as follows:

Enhance access to cancer diagnosis and treatment

There are several issues that arise due to inaccessibility of cancer care services. Most of the tertiary cancer care centres in India are in the cities. There is a huge delay in diagnosis and/or treatment during presentation. The availability of cancer care closer to homes has helped in early detection, diagnosis and treatment of cancer, leading to improved outcomes.

One of the key findings which has emerged is the improve in access to cancer care in smaller towns during the COVID-19 pandemic. The frequent lockdowns, restricted travels and fear of contracting COVID-19 prevented patents from travelling to cancer centers for diagnosis, treatment and follow-up (Ranganathan et al., 2021). The risk of delays could potentially lead to tumor progression and poorer outcomes.

Treatment outcomes

Karkinos Healthcare engages with the patient in the early stages of the disease, provides contextualized and comprehensive patient demographic and clinical information. This enables clinicians to arrive at a comprehensive approach to disease treatment and progression monitoring quickly and

avoid errors and duplications in prescriptions and procedures, ensuring better treatment outcomes for the patient. Expert oncology guidance from world renowned oncologists through the virtual tumor board is creating benefit of scale by pooling cases across the partners.

Improved patient experience

The central command center of Karkinos Healthcare has ensured efficient patient navigation and visit management, which has helped accelerate the overall workflow of healthcare delivery to reduce patient wait times while enabling better utilization of health professionals' time and hospital resources.

6.2. Innovation

A distributed model through a managed tiered approach to cancer centre development can deliver equality in cancer care, including improved integration between individual cancer centres to deliver comprehensive cancer care on common guidelines, training, and research networks. Where availability of high skilled manpower in oncology is a major challenge, technological advancements can bridge this gap.

The solution encompasses a 'hub-and-spoke and further spoke' hospital infrastructure on the back of a robust technology and clinical decision support systems that enables service delivery in a wide patient catchment. The design and delivery will be through bespoke solutions for cancer care, as a one-stop-shop in experience, addressing core clinical needs for this specialised health sector through a digitally enabled distributed cancer care network that will bring quality care closer to patients in the cancer care continuum.

The study describes a delivery model for LMICs like India to improve cancer care outcomes by -

- Stage shift in cancer diagnosis from a late stage to an early-stage diagnosis of patients by focusing on screening the population for cancers, while partnering with general practitioners, nurses,

community health workers to arrive at standardised protocols for cancer screening that can be done at scale

- Create newer touch points across the patient's treatment pathway by involving patient care coordinators, nurses, doctors, general physicians, community healthcare workers who are all updated about the pathway for the patient's under their care
- Enable distributed cancer care more on the back of a robust distributed architecture for enabling the key value proposition for the various customer segments
- Design an interpretive and evidence-based models for implementation and innovation at the grassroot level
- Delivery of the treatment protocols and the care pathways to the patients, allowing the patient's to get up-to-date information of current status of their treatment and knowing the future roadmap from the oncologists
- Using technology and AI based solution for continuous feedback to improvise care to the patient and the family

6.3. Recommendations for future work

Introduction of cancer screening programme is associated with reduction in cancer related mortality rates as detection and care during early stage vastly improves the chances of survival. We have elaborated on the implementation process and success of a distributed model in Kerala to not only improve cancer screening but also provide an easy and accessible pathway for the screened positives with the help of patient navigation from the command center.

The initial data and experiences indicate that the platform has been useful for those in need. For many patients who have previously gone through multiple consultations, the distributed cancer care model has been instrumental in saving time as well as reducing out-of-pocket expenditure

due to closer access to care. Generally, cancer suspected or diagnosed patients rely on cancer centers located at the cities. This creates accessibility issues which is one of the reasons for delay in diagnosis and treatment, and the COVID-19 pandemic made this situation worse across India, particularly in smaller towns and rural areas (Pramesh et al., 2021) such as Idukki district with no cancer centers nearby.

There is higher need to decentralise cancer care in India. The proposed model could be replicated across in several States of India which are reporting high burden of cancer. Discussion are at advanced stages with 20+ partners in state of West Bengal and Manipur who are interested to implement the model.

The findings from this study demonstrate the ability of technology-enabled DCCM to successfully screen and detect cancer at the peripheral-level and to converge the actions of various private health facilities towards providing a continuum of cancer care.

Based on the learnings from the pilot intervention in Kerala, the important success parameters to assess the quality and effectiveness of the interventions in a new geography would include the demonstration of the key metrics (defined below) in a geographic catchment area which may be defined as a “cluster.”

The hub and spoke and further spoke model in a cluster, of around 100 kms, would be centered around a comprehensive cancer center providing all modalities of treatment, and will be supported by a number of spokes providing prevention and diagnosis along with appropriate treatment.

Intervention at a cluster-level using the DCCM involves a process and pathway so that no person is denied of care due to lack of acces, affordability and quality. It involves end-to-end care for every citizen enabled effectively and efficiently with the help of patient navigation and data insights through technology. Mapping the pathway to the existing health facilities is necessary to describe how people move through the pathway, from identification of the target population for prevention and screening to

diagnosis and treatment. Each step of the pathway should be supported by standards, protocols and guidance using the best available evidence.

Addressing the following questions become critical while planning to establish a DCCM for a cluster-wide population in any geography -

What is the total eligible population for screening for the common cancers in the cluster? What is the current cancer burden in the cluster? Are the existing cancer diagnoses and care pathways strong and resilient enough to bear the extra effort of a high-quality screening programme? Who are the stakeholders who are willing to participate to provide the continuum of care? Are the stakeholders willing to work on clear and transparent clinical protocols and follow careful objective appraisal of evidence of efficacy and effectiveness? Are these decisions based on strong evidence?

The key metrices to be measured for effective and efficient delivery of care across the pathway here would include total number of eligible population screened for common cancers, number of screened postives/ detected and referred for continued care, number of people successfully followed up within a defined time interval, time from detection to diagnosis, stage at diagnosis, time taken for the confimed cases / cancer positive to initiation of treatment, lost to follow-up for treatment, cost of treatment and out-of-pocket expenditure, access to cancer care centers, waiting times and survival rates.

Implementing this ambitious project for a cluster-wide population involves a multiple stakeholders orchestration for which the criteria for selection and implementation have been shown in this study and can be used across a wide population catchment in India.

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