RESEARCH ARTICLE

Editorial Process: Submission:08/03/2024 Acceptance:08/30/2025 Published:09/12/2025

Spatial Analysis of Travel Distances for Persons with Common Cancers Seeking Care at a Tertiary Care Facility in South India: An Operational Research

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Abstract

Background: Accessibility is an important determinant of healthcare facility utilization. However, there is limited data on patient travel distances to reach cancer treatment facilities. Therefore, this study aimed to determine the geographical location, travel distance and travel time to the cancer centre for persons with cancer (PWC) at a tertiary care facility in Southern India. **Methods:** The locations of PWC were geocoded utilizing ArcGIS World Geocoding Services, and network analysis was performed using the ArcGIS Pro Business Analyst Geoprocessing extension. Simple median regression was performed to assess the relationship between sociodemographic and clinical variables for both distance and time. **Results:** Among 1306 persons with common cancer, the mean (SD) age was 51.7 (8.8) years, with 73.5% female, 65.3% residing in rural areas, majority (33% breast cancers), and 34% stage III]. Median travel distance (IQR) for PWC from their residences to the tertiary care facility was 96.2 (36.4–155.7) km, while the median travel time by driving was 154.8 (72.5–235.3) minutes. In 78 % cancer care centres were available within 25 km. Males, individuals residing in rural areas, those with late-stage cancer, and individuals with lip-oral, oesophageal, and stomach cancer tend to travel more than their counterparts for cancer care. **Conclusion:** The study concludes that more than three-fourths of patients with cancer travel longer distances despite having a nearby cancer care facility.

Keywords: Cancer burden- Geographical information system- Access to healthcare- Travel distance- Oncology services

Asian Pac J Cancer Prev, **26 (9)**, 3211-3219

Introduction

Cancer is a leading cause of mortality globally, being the first or second leading cause in 112 countries and the third or fourth in another 23 countries [1]. According to the Global Cancer Observatory's GLOBOCAN 2022 report, there were approximately 20 million new cancer cases worldwide. Nearly half of these cases, 49.2%, were in Asia, which also accounted for 56.1% of the 9.74 million global cancer-related deaths. In India alone, there were an estimated 1,413,316 new cancer cases and 916,827 cancer-related deaths in 2022, indicating a significant cancer burden [2].

Access to quality healthcare services is a key factor in achieving the Sustainable Development Goal for Universal Health Coverage. In India, those who require healthcare the most often face the most significant barriers to accessing medical services, making them the least likely to have their health needs addressed [3]. Cancer treatment generally relies on three primary methods: surgical oncology, chemotherapy, and radiation therapy [4]. However, oncology services in India are limited in rural and select urban areas. As a result, patients often need to travel long distances to reach cancer centres, which are primarily located in cities [5]. Studies have shown that patients treated for cancer at high-volume hospitals tend to have better outcomes [6, 7]. This trend toward specialization leads to centralization, increasing the distance patients must travel from their homes to facilities that offer comprehensive cancer diagnosis and

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treatment [8, 9].

Greater distances to healthcare facilities can limit access and reduce the frequency of visits, [10, 11] this distance can reduce adherence to treatment and result in poorer cancer outcomes for those living in rural areas or far from treatment centres [12, 13]. The distance travelled has a direct effect on the cost of care. According to studies, the expenses associated with travel and lost wages are significant factors in the healthcare costs faced by PWC [14, 15]. In response to this challenge, the Government of India (GoI) has implemented the National Programme for Non-Communicable Diseases (NP-NCD), which includes the establishment of day care centers in District Hospitals for ongoing chemotherapy following initial treatment at tertiary care centers. District Hospitals maintain connections with State Cancer Institutes and tertiary care cancer centers, ensuring a smooth continuum of care. This strategic initiative aims to mitigate patient inconvenience and reduce expenditure [16, 17].

The primary focus of the study is on travel distances for cancer care. In the context of India, there is a significant gap in the literature as studies related to travel distance for accessing cancer care are not available. This research aims to fill that gap by providing valuable data on travel distances, which can inform healthcare policies and improve the delivery of cancer care services in India. In this study, we used spatial analysis to assess travel distances. We aimed to identify the geographic location and road distances to cancer care facilities for patients seeking treatment at a tertiary care centre, an Institute of National Importance, in Southern India. Additionally, we sought to ascertain the nearest public cancer care facility and the most efficient route to these healthcare facilities while also comparing the distances travelled based on socio-demographic characteristics.

Materials and Methods

Study design and setting

A cross-sectional analytical study was conducted among PWC receiving treatment at one of the Regional Cancer Centres (RCCs) located in the southern part of India, specifically in Puducherry, from September to December 2023. The facility is located in the union territory of Puducherry and serves patients from nearby districts in Tamil Nadu. Puducherry covers an area of 293 km² and has many large teaching hospitals as well as numerous private healthcare providers. There are 36 medical college hospitals and 36 district hospitals in Tamil Nadu. Almost every district has both a medical college hospital and a district hospital. The government of Tamil Nadu provides free diagnosis and treatment for cancer care to those below the poverty line through these facilities. Our RCC has medical, surgical and radiation oncology departments on campus; it provides Outpatient, Inpatient and Day Care. The facility provides cancer care to 3,000 new cancer patients and approximately 40,000 follow-up patients annually.

Study population

A study included persons with five common adult (ages 18-65 years) cancers: breast, lip-oral cavity, cervix uteri, lung, and oesophagus cancer, sought treatment at our centre and who belonged to the states of Tamil Nadu and Puducherry between January and December 2022. Data on age, gender, residential address, residential area, cancer type, and stage were obtained from the JIPMER hospital-based cancer registry (HBCR).

Ethical clearance

The study was approved by the Institutional Ethics Committee JIPMER, Puducherry, India (IEC approval number: JIP/IEC-OS/071/2023).

Study procedure

All eligible PWC house locations were geocoded using ArcGIS World Geocoding Services based on street names, resulting in 1,306 matched locations. Geo locations of medical college hospitals and district hospitals were obtained from the National Health Mission of Puducherry and Tamil Nadu.

Distance calculation

Our study utilized the ArcGIS Pro Business Analyst Geoprocessing extension for network analysis to calculate road/driving distances to the RCC and the nearest medical college or district hospital. Using the coordinates of patients' current residences, we computed network distances (Manhattan distance) to the RCC. This road-based network analysis included all car travel on national highways, state highways, and residential roads. The ArcGIS Online Routing services, set to driving or rural driving mode, were used to ensure compliance with one-way streets, legal turn restrictions, and other car-specific regulations. The analysis considered various factors such as natural barriers (e.g., rivers), street directions, accessibility, built environment features, and interstate highways.

To estimate travel time, ArcGIS software utilized the 'Car travel mode.' The network analysis optimized travel by accounting for attributes such as impedance, time cost, and speed limits, which were set to reflect rural driving speeds. The travel modes employed network hierarchy restrictions to optimize travel time to the nearest facility, such as a medical college or district hospital, with vehicle movements modelled for cars and pickup trucks. Dynamic travel speeds based on real-time traffic conditions were used where available. Speed limits were adjusted according to rural driving speeds, with statutory limits set at 25 km/h for residential or rural roads, 55 km/h for state highways, and 70 km/h for national highways under ideal conditions. All distances were measured in kilometres, and travel times were recorded in minutes.

Statistical analysis

Spatial analysis was conducted using ArcGIS Pro software (Environmental Systems Research Institute, Redlands, CA), while quantitative analysis was performed using Stata version 14. All patient data underwent anonymization before analysis. Continuous variables such as age were presented as mean (standard deviation), while categorical variables such as gender, area, state

of residence, cancer type, and stage were presented as proportions. The distance to the nearest public care site was categorized as either within 25 km or >25 km. PWC travel distance and time were summarized as median (interquartile range). Median regression analysis was employed to compare median values among different patient groups, with a p-value of less than 0.05 considered statistically significant.

Results

A total of 1,306 PWC, mean (SD) age of 51.7 (8.8) years, with 75% being over 45 years old. The cohort comprised 73.6% females, 65.3% from rural areas, and 82.1% from Tamil Nadu state. Among them, 32.8% were diagnosed with breast cancer, and 33.5% were in stage III cancer. The sociodemographic characteristics of the PWCs are described in Table 1.

The network diagram in Figure 1 illustrates the spatial distribution of the study participants. The median travel distance (IQR) for PWC from their residences to the Tertiary Care Facility was 96.2 (36.4–155.7) km, while the median travel time (interquartile range) by driving was 154.8 (72.5–235.3) minutes. Figure 2 depicts the spatial distribution of PWC and public cancer care facilities (Medical College Hospital and District Hospital). The median distance between PWC residences and the nearest healthcare facility was 14.2 (5.5-23.9) km. About 77.8% of PWC residents are within a distance of less than 25 km from a healthcare facility, yet they travel long distances to seek treatment. The Network analysis of travel distance between the residence of PWC's home to their nearest public cancer care facility is shown in the supplementary File (Figure 3).

Table 2 reveals notable disparities based on socio-demographic factors and clinical variables. Specifically, a significant difference was observed based on gender, with males travelling significantly longer distances than females (111.4 km vs. 90.6 km, $p = 0.002$). PWC residing in rural areas travelled significantly farther distances compared to urban dwellers (110.0 km vs. 44.5 km, $p < 0.001$).

Furthermore, travel distances varied across different cancer sites and stages. For instance, individuals with lip or oral cavity and Upper GI cancer travelled significantly farther distances compared to breast cancer patients ($p < 0.05$). Regarding cancer stage, individuals diagnosed with late stage cancer travelled significantly longer distances compared to those with stage I cancer ($p < 0.05$).

Table 3 illustrates a comparison of the time spent by PWC to access care at the tertiary care facility. Significantly longer durations were observed for seeking care among younger individuals, males, PWC from rural areas, residents of Tamil Nadu, and those with cancer types affecting the oral-lip or upper GI sites, particularly those in the late stage.

Discussion

To our knowledge, this is the first study in India using spatial analysis to determine the travel distances of PWC seeking care at a tertiary care facility. The majority of participants were aged 45 years and above, predominantly female, and residing in rural areas, accounting for nearly 75% of the sample. The study revealed that PWC travelled significant distances to access care. Using ArcGIS Pro we utilized the 2-Step Floating Catchment Area (2SFCA) method to identify the nearest healthcare facilities using the shortest routes. The 2SFCA method has been widely used in numerous studies to estimate spatial access to healthcare services [18, 19].

Many research studies have shown how the distance between a patient's home and the hospital affects their chances of survival and their overall quality of life, both during cancer treatment and after they become cancer survivors [20–22]. In this study, data from an HBCR in 2022 involving 1306 PWCs revealed a median travel distance of 96.2 km (IQR 36.4-155.7 km) to reach for the current cancer treatment facility. This is higher than the reported median travel distance of 18 km (IQR 6-34 km) to specialized cancer care and diagnosis in Denmark [23]. In another study conducted in British Columbia, Canada, in the year 2016, the median travel distance to cancer treatment was 18.8 km (IQR: 8.4-99.0) [24].

Table 1. Sociodemographic Characteristics of Persons with Cancer Attending a Tertiary Care Facility, Puducherry during 2022. (N=1306)

Variable	n	%
Age in years		
18-45	325	25
≥ 46	979	75
Gender		
Female	961	73.6
Male	345	26.4
Residence		
Rural	853	65.3
Urban	453	34.7
State		
Tamil Nadu	1072	82.1
Puducherry	234	17.9
Cancer site		
Breast	429	32.8
Lip, oral cavity	271	20.8
Cervix Uteri	357	27.3
Lung	53	4.1
Upper GI (Oesophagus & Stomach)	196	15
Stage		
I	69	5.3
II	345	26.4
III	438	33.5
IV	285	21.8
Missing	169	12.9
Driving distance to nearest public cancer care facility		
≥25 km	290	22.2
<25	1016	77.8

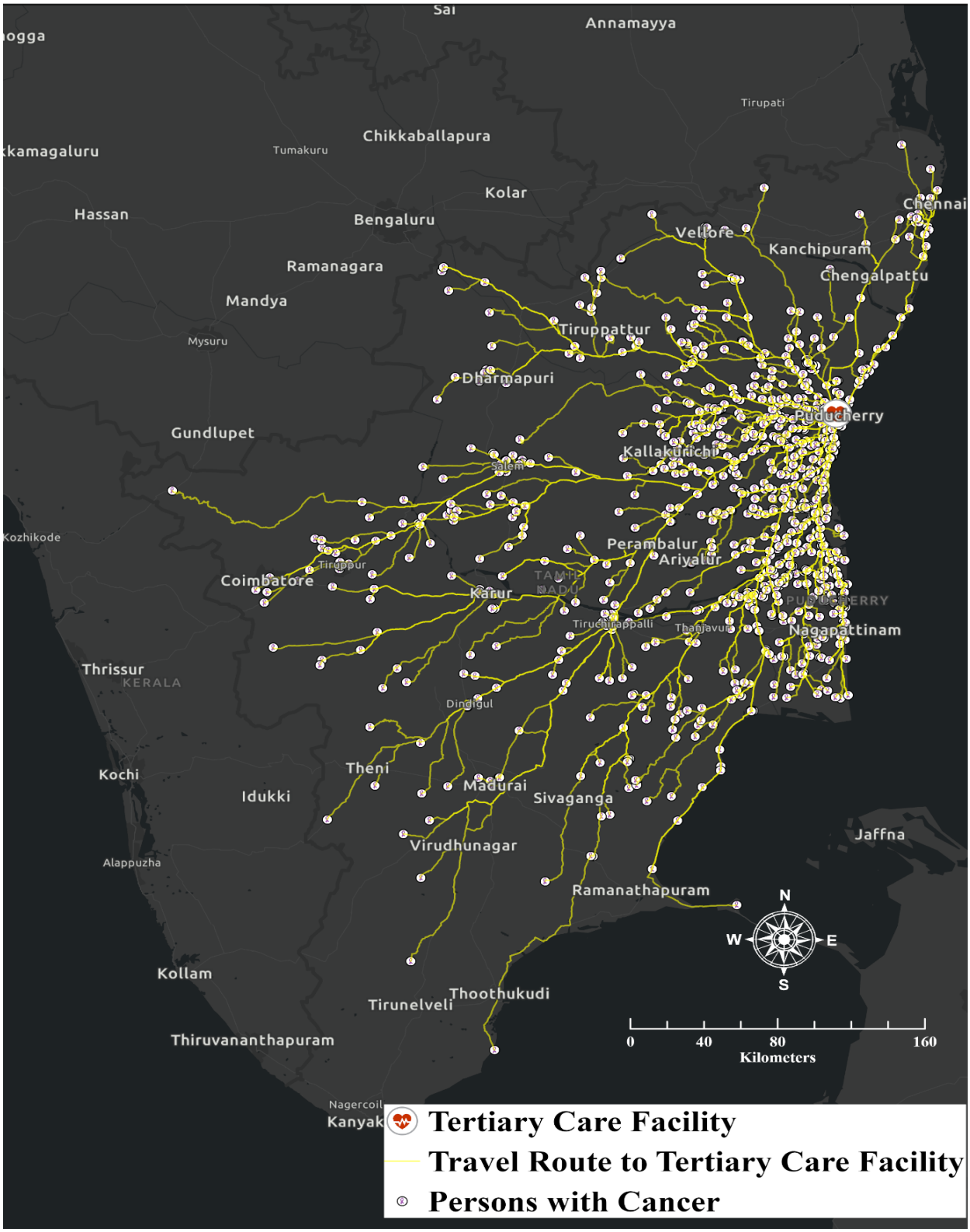

Figure 1. Geographic Locations and Travel Distances of Persons with Cancer Attending a Tertiary Care Facility, Puducherry, (N=1306)

Additionally, a study conducted in Brazil, an upper-middle-income country, reported that individuals travelled a median distance of 187.3 km (IQR 96.7-290.9 km) to receive chemotherapy [25]. Both developed countries reported less travel distances for cancer care compared to developing countries.

Our study found that based on the residence of PWCs, the median (IQR) travel distance to reach the tertiary care facility was 110 km (IQR 61.3-175.5 km) for rural residents, which was more than two times that travelled by urban residents (median=44.5 km (IQR 5.6-132.5 km)). This study adds to the well-documented urban-rural disparity in cancer care in India [26–28]. In comparison, a study in Canada focused on travel distance

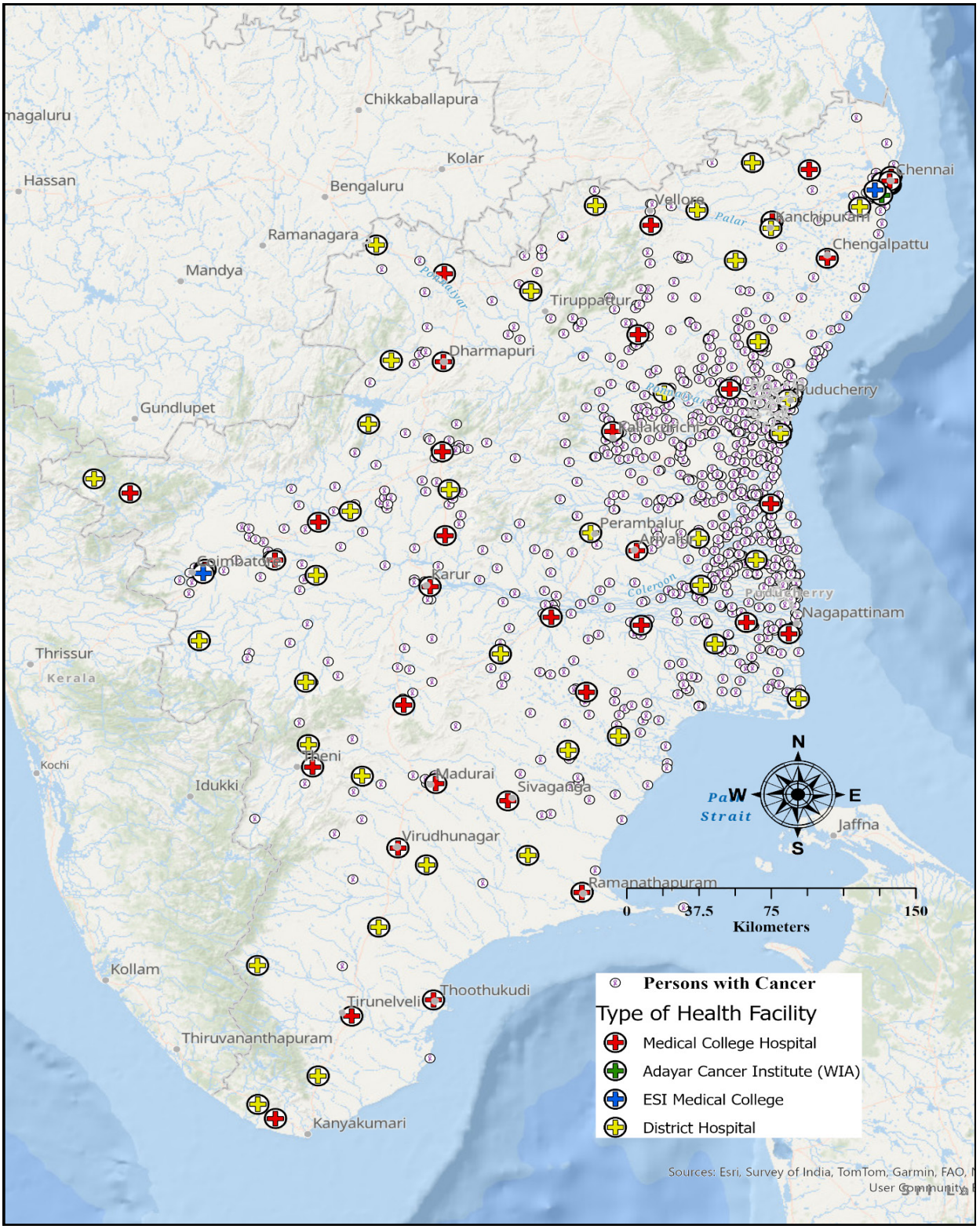

Figure 2. Spatial Distribution of Residential Areas and the Nearest Public Cancer Care Facilities of Persons with Cancer s Attending a Tertiary Care Facility, Puducherry, (N=1306).

for cancer care related to urban and rural areas to reach multidisciplinary management [24]. They reported a median (IQR) travel distance of 94.3 km (IQR 40.6-267.5 km) for rural residents and 15.9 km (IQR 9.4-35.6 km) for urban residents. This was lower than that noted for both urban and rural residents from our study. Moreover, the ongoing improvements in cancer treatment could make the gap in outcomes for rural patients worse unless deliberate actions are taken to understand and overcome the barriers to accessing high-quality care in these areas [29].

Most individuals with late-stage common cancer travel more than 95 km, significantly. Studies indicate that metastatic cancer requires treatment by multidisciplinary specialists [30]. Ayushman Bharat - Pradhan Mantri Jan Arogya Yojana (PMJAY) or the flagship National Health Protection Scheme, is funded by the Government of India

Table 2. Comparison of Travel Distance of Persons with Cancer Attending Cancer Care in a Tertiary Care Facility, Puducherry (N=1306).

Variable	n	Manhattan Distance (Kms)*		p value
		Median (IQR)	Unadjusted coefficients (95% CI)	
Age in Years				
18-45	327	98.7 (36.9-164.3)	4.2 (-13.3 to 21.5)	0.639
≥ 46	979	94.3 (35.8-152.8)	1	-
Gender				
Male	345	111.4(54.8-181.8)	20.8 (7.6-34.0)	0.002
Female	961	90.6 (32.0-146.3)	1	-
Residence				
Rural	853	110.0 (61.3-175.5)	65.5 (53.4-77.6)	<0.001
Urban	453	44.5 (5.6-132.5)	1	-
State				
Tamil Nadu	1072	109.9 (63.7-179.0)	104.5 (93.6-115.4)	<0.001
Puducherry	234	5.5 (3.4-9.5)	1	-
Cancer site				
Breast	429	84.5 (16.6-144.7)	1	-
Lip, oral cavity	271	115.1 (60.1-176.7)	30.6 (13.6-47.7)	<0.001
Cervix uteri	357	88.0 (37.9-138.5)	3.5 (-12.2-19.2)	0.658
Lung	53	88.0 (35.6-190.3)	3.5 (-28.4-35.5)	0.828
Upper GI (Oesophagus, Stomach)	196	111.0 (51.2-183.5)	26.8 (7.9-45.7)	0.006
Stage				
I	69	69.5 (20.5-132.8)	1	-
II	345	81.7 (26.8-136.1)	15.3 (-11.3-41.8)	0.26
III	438	97.2 (43.9-171.4)	27.7 (1.6-53.8)	0.037
IV	285	111.2 (47.3-179.7)	41.7 (14.7-68.8)	0.003
Driving distance to nearest public cancer care facility				
≥25 km	290	31.5 (27.4-37.5)	25.6 (24-25.1)	0.354
<25	1016	9.4 (4.2-11.7)	1	-

CI, Confidence interval; IQR, Inter quartile range; kms, Kilometres

[4]. The program is working closely with the National Cancer Grid, a network of major cancer centres across the country, to ensure that protocols are followed for cancer surgeries, chemotherapy, radiation therapy, and other cancer treatments provided under the scheme. In order to improve patient accessibility and reduce out-of-pocket expenditures for indirect medical costs such as travel, food, and accommodation, the Government of India's NP-NCD program and Tamil Nadu state policies for cancer care suggest that initial treatments, such as diagnosis and surgery, should be conducted at tertiary care facilities, while chemotherapy and follow-up services can be availed at nearby district hospitals [16, 17]. This study observed that three-fourths of PWCs had a cancer care facility, either a Medical College Hospital or a District Hospital, within a 25-kilometer radius of their residence. Despite this proximity, a significant number of individuals still opted to travel from their residence to tertiary care facilities for treatment. By implementing and monitoring the down referral system effectively and ensuring the availability of cancer care at Medical College Hospitals and District Hospitals, we can enhance accessibility and reduce the need for lengthy travel. Strengthening the health system for cancer care is crucial to achieving these goals.

Strength and limitations

This study aligns with the revised operational guidelines of NP-NCD 2023 regarding down-referral and follow-up cancer care in District Hospitals and Tertiary Care Centers. This work contributes to the foundation for the need to decentralise care as envisaged under the NP-NCD 2023. The impact of travel on treatment continuation and treatment outcome was not studied. For this objective, determining geographical locations and road distances travelled for seeking cancer care using GIS is limited by the assumption of PWC driving to the tertiary care facility, as the actual mode of transportation is unknown. We included only one tertiary care centre in the study.

In conclusion, a considerable number of individuals with cancer travel long distances despite having District Hospitals and Medical College Hospitals within 25 kilometres. Specifically, males, individuals residing in rural areas, those with late-stage cancer, and individuals with lip-oral, oesophageal, and stomach cancer tend to travel more than their counterparts for cancer care. The study findings indicate that adopting the down-referral

Table 3. Comparison of Travel Timing of Persons with Cancer Attending Cancer Care in a Tertiary Care Facility, Puducherry (N=1306)

Variable	n	Driving time in minutes		p value
		Median (IQR)	Unadjusted coefficients (95% CI)	
Age in Years				
18-45	327	158.8 (66.2-238.1)	7.9 (-5.2 to 20.9)	0.237
≥ 46	979	154.6 (72.7-235)	1	-
Gender				
Male	345	177.0 (93.6-258.5)	30.7 (13.0-48.4)	0.001
Female	961	146.3 (55.7-225.2)	1	-
Residence				
Rural	853	175.8 (111.0-258.6)	80.1 (61.4-98.7)	<0.001
Urban	453	95.7 (16.9-204.7)	1	-
State				
Tamil Nadu	1072	175.9 (112.6-262.9)	160.5 (146.0-175.1)	<0.001
Puducherry	234	15.4 (11.0-24.6)	1	-
Cancer site				
Breast	429	134.8 (34.1-221.0)	1	-
Lip, oral cavity	271	184.8 (109.3-255.9)	50.0 (28.0-72.0)	<0.001
Cervix uteri	357	142.3 (79.8-220.7)	7.5 (-12.8-27.8)	0.466
Lung	53	146.3 (63.5-256.5)	11.5(-29.8 to 52.7)	0.585
Upper GI (Oesophagus, Stomach)	196	172.0 (97.4-272.0)	39.6 (15.2-64.1)	<0.001
Stage				
I	69	116.7 (43.4-211.1)	1	-
II	345	135.9 (45.0-215.3)	19.1 (-16.5-54.7)	0.293
III	438	156.7 (85.1-239.8)	40.5 (5.5-75.5)	0.023
IV	285	177.5 (85.4-257.3)	60.7 (24.5-97.0)	0.001
Driving distance to nearest public cancer care facility				
≥25 km	290	61.3 (51.3-77.9)	39.8 (36.5-43.1)	<0.001
<25	1016	21.5 (12.6-36.1)	1	-

CI, Confidence interval; IQR, Inter quartile range

model for cancer care after strengthening the cancer care services at the District Hospitals and the Medical College Hospitals, would improve access and reduce the travel burden.

Author Contribution Statement

L.D, M.T, P.G: Conceptualization, Methodology, Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project Administration. J.D, S.P.A: Formal analysis, Data curation, Supervision, Writing - Review & Editing, Project Administration. S.K.S, G.K, J.J.O: Supervision, Writing - Review & Editing. All authors contributed to finalise the manuscript.

Acknowledgements

The authors sincerely thank the Hospital Based Cancer Registry (HBCR), JIPMER, for providing access to the data utilized in this study.

Funding statement

This study was conducted as part of the Master of Public Health (MPH) program and was supported by an intramural grant from the Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER). Puducherry. (Approval number: JIP/Res/Intramural/Phs-1/2023-24).

Ethical clearance

The study was approved by the Institutional Ethics Committee JIPMER, Puducherry, India (Approval number: JIP/IEC-OS/071/2023).

Availability of Data

The dataset used for this study is available from the corresponding author upon reasonable request.

Conflict of interest

No potential conflict of interest was reported by the author(s).

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