Geographic Information System (GIS) in Evaluating the Accessibility of Healthcare Facility for Patients with Colon and Rectal Carcinoma in the State of Kelantan and Sabah

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Abstract

Malaysian National Cancer Registry (MNCR) 2007-2011, has ranked colorectal cancer (CRC) as the most common cancer for men and the second most common cancer for the women. We investigated the distribution of CRC patients and their accessibility to government healthcare facility using spatial analysis in both states. This is a retrospective cross-sectional study of patients who were diagnosed with CRC in the state of Kelantan and Sabah from the year 2016 till 2018. A total of 363 and 589 patients from Kelantan and Sabah respectively were recruited into the study. QGIS was used to create a distribution map and spatial analysis (average nearest neighbour and hotspot analysis) was performed with ArcGIS. The average age of patients with CRC in the state of Sabah was lower than that of Kelantan. The results from the average nearest neighbour suggest clustered pattern for both states. Hotspot analysis showed focused area on cluster in Kelantan over the northeast region. Spatial analysis shows both states to have patients with CRC who travelled more than 10km to reach the nearest hospital. GIS provides an alternative method of data analysis in comparison to conventional tabular form for CRC cases in Kelantan and Sabah.

1. Introduction

According to Malaysian National Cancer Registry (MNCR) 2007-2011, colorectal cancer (CRC) is ranked as the most common cancer for men and the second most common cancer for the women with the age standardized rate of 14.6 and 11.1 incidence per 100,000 population respectively (Azizah et al., 2011). An effective screening program is need for early detection of CRC which results in better overall prognosis for the patients. Geographic Information Systems (GIS) is a computer-based tool that analyses, stores, manipulates and visualizes geographic information, usually in a map. Over the years this system has been used for several healthcare related studies both internationally and locally which has generated many positive outcomes. We plan to use GIS to evaluate the accessibility of patients with CRC to the existing health care facility especially in Kelantan and Sabah. This research will also enable us to investigate distribution of CRC and accessibility to government healthcare facility using spatial analysis in both states.

Globally, majority of the highest colorectal cancer incidence rates among males were observed in Europe, North America, and Oceania. High rates were also noted in Japan and Singapore and this is most likely due to environmental or lifestyle factors, (Center et al., 2009). GIS technology provides researchers, practitioners, policy makers and other decision makers the ability to integrate health data with mapping functions and allow for in-depth investigation, exploration, visualization, and modelling of health outcomes patterns (Graves, 2008). This system has been utilized for 15 years in

public health to analyse and compare data related to a disease in a particular area. Diseases such as cholera and dengue have been mapped to rule out the relationship between the diseases and other environmental and spatial characteristics (Samad et al., 2010).

There is strong relationship between the presenting symptoms and the location of the colorectal cancer. This study will be helpful in our clinical practice by choosing the appropriate investigation method for our patients for diagnosis and screening of high-risk groups, which may be cost effective and less time consuming, preventing any delay in management process. We would like to suggest to start proper CRC screening program in Malaysia for better prognosis and survival in future (Maad Ahmed Samem et al., 2018).

2. Research Methodology

2.1 Research Design

This is a retrospective cross-sectional study of patients who were diagnosed with CRC in the state of Kelantan and Sabah from the year 2016 till 2018. A total of 363 and 589 patients from Kelantan and Sabah respectively were recruited into the study. The study area includes Kelantan State Health Department and Sabah State Health Department. The source of the population would be from patient who were diagnosed with colorectal cancer in the state of Kelantan and Sabah with records provided by the state health department. The inclusion criteria will be Malaysians who are residing in the State of Kelantan and Sabah and have been diagnosed with colorectal cancer with evidence form histopathology. Subjects who had incomplete histopathological diagnosis and addresses which coordinates could not be obtained were excluded. Patients with incomplete cancer staging were stated as unspecified in the results section for respective states. We used GIS software to analyse the locations of the patients with CRC in both states and evaluated with spatial tools the distribution and accessibility of patients with CRC to nearest healthcare facilities. The research is aimed to streamline the screening for CRC in both states.

2.2 Sample size

The sample size calculation for this study was done using Sample Size Calculator (spreadsheet), version 2.0. The sample size was calculated under proportion -estimation (Naing, 2006). The prevalence was 13.20 % as per the Malaysian Cancer Registry for Colorectal Cancers between the year 2007 till 2011 (Azizah et al., 2011). The total number of patients required are 197 and with drop-out consideration 177 patients are required. The sample size represents for the state of Kelantan and Sabah (197 patients for respective states).

2.3 Data aAnalysis

The details (address, gender, age, ethnicity and stage) of patient with CRC will be collected from the State health department of Kelantan and Sabah. These details will be transferred Microsoft Excel prior to analysis using the GIS software (QGIS and ArcGIS). The coordinates were obtained via google maps from the addresses provided in the data by the respective state health departments. The coordinates of government hospitals were obtained from the Ministry of health. These data were stored in csv format for further analysis using GIS software. Ethical approval was attained from the Research and Ethics Committee of Hospital Universiti Sains Malaysia (HUSM), National Medical Research Registry (NMRR) and Medical Research and Ethics Committee (MREC) were also obtained.

QGIS version 3.12.1 and ArcGIS version 10.2 by ESRI were used for data analysis. The coordinates were attained with google maps and a csv format file was created. Those data was uploaded to QGIS and distribution map was obtained. Further spatial analysis was performed in ArcGIS with the same coordinates. ArcGIS was used to produce spatial analysis of average nearest neighbour and hotspot analysis (Optimized Hotspot Analysis). The average nearest neighbour will be able to indicate if cases are clustered or merely by random. Increment of Z score value will represent a more extreme clustering. Both analyses will be used for the objectives of the study. Further, buffer analysis was used to evaluate patients who are situated within 10km of 2 or more hospitals.

3. Results

3.1 Patients Characteristics

The total number of registered colorectal cancer (CRC) between the year 2016 till 2018 in the state of Kelantan and Sabah were 363 and 589 respectively. The average age for patients with colorectal cancer in the state of Sabah was lower than that of Kelantan. Patients with CRC in Sabah were mostly from the age of 51-60 years old which represented 28.9%. Alternatively, the highest percentage of patients with CRC from Kelantan ranged between 61-70 years old. The distribution between male and female patients with CRC from Kelantan was almost equal, 50.4% male and 49.6% female. However, the state of Sabah showed an unequal distribution in which majority of patients with CRC were females representing 64.7%. Malay ethnic with CRC were the highest in the state of Kelantan representing 89.5% whereas in Sabah,

Chinese represented the most patients with CRC, which is 32.6%. On the other hand Kadazan, is the second with 19%, followed by Bajau 17.8 %. Other ethnicity constitutes for 26.5% are represented by 13 ethnic groups in Sabah (Tables 1-2).

3.2 Disease Characteristic

Patients with colon cancer is higher than those with rectal cancer, which constitutes for 63.8% and 65.3% in Sabah and Kelantan respectively. Most patients were diagnosed with CRC at an advanced stage in both states. More than half of them presented at stage 3 and 4 in both states. Although the data was taken from the state health department from respective states, the stages of cancer for some patients were not specified. Nevertheless, we have included those number as unspecified which constitutes for 93 patients and 167 patients for Kelantan and Sabah respectively.

3.3 Distribution and Spatial Analysis

The patients' data from the state health department was analysed and those who fit the inclusion criteria were included in the study. Although most of the data provided by the state health department from both states included addresses, there were incomplete or unavailable addresses leading to unobtainable coordinates which is represented in Table 3. Addresses of government hospitals in both states were taken from Ministry of Health Malaysia and their coordinates were included for geographical analysi (Table 3).

Table 1: Demographic and disease characteristics of patient with colon and rectal cancer by year, age, gender, ethnicity, Location of cancer, and stage in State of Kelantan (n=363)

Characteristics		**n(%)**
Year	2016	160 (44)
	2017	95 (26)
	2018	108 (30)
Age	<20	2 (0.5)
	21-30	9 (2.5)
	31-40	25 (7.0)
	41-50	43 (11.8)
	51-60	92 (25.3)
	61-70	110 (30.3)
	71-80	67 (18.5)
	>80	15 (4.1)
Gender	Male	183 (50.4)
	Female	180 (49.6)
Ethnicity	Malay	325 (89.5)
	Chinese	33 (9.1)
	Indian	-
	Others	5 (1.4)
Location of cancer	Colon	237 (65.3)
	Rectum	126 (34.7)
Stage	1	13 (3.6)
n=270	2	56 (15.4)
	3	77 (21.2)
	4	125 (34.2)
	Unspecified	93 (25.6)

Table 2: Demographic and disease characteristics with colon and rectal cancer by year, age, gender, ethnicity, Location of cancer, and stage in State of Sabah (n=589

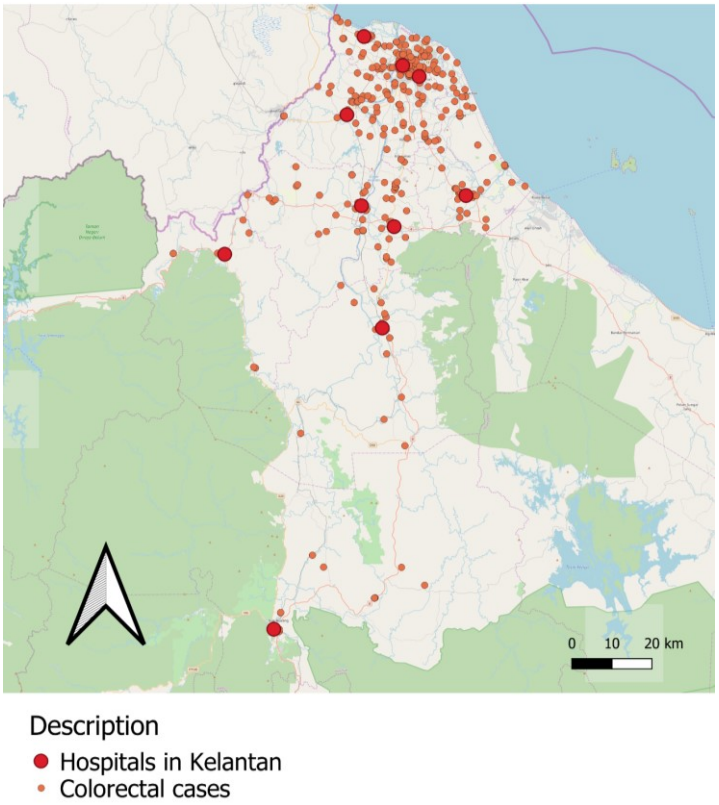
Characteristics		**n(%)**
Year	2016	219 (37)
	2017	179 (30)
	2018	191 (33)
Age	<20	5 (0.8)
	21-30	5 (0.8)
	31-40	34 (5.8)
	41-50	75 (12.7)
	51-60	170 (28.9)
	61-70	158 (26.8)
	71-80	104 (17.7)
	>80	38 (6.5)
Gender	Male	208 (35.3)
	Female	381 (64.7)
Ethnicity	Malay	24 (4.1)
	Chinese	192 (32.6)
	Bajau Kadazan	105 (17.8) 112 (19)
	Others	156 (26.5)
Location of cancer	Colon	376 (63.8)
	Rectum	213 (36.2)
Stage	1	29 (4.9)
n=422	2	57 (10.0)
	3	122 (20.6)
	4	214 (36.2)
	Unspecified	167 (28.3)

Table 3: Coordinates used for GIS mapping in the State of Kelantan and Sabah

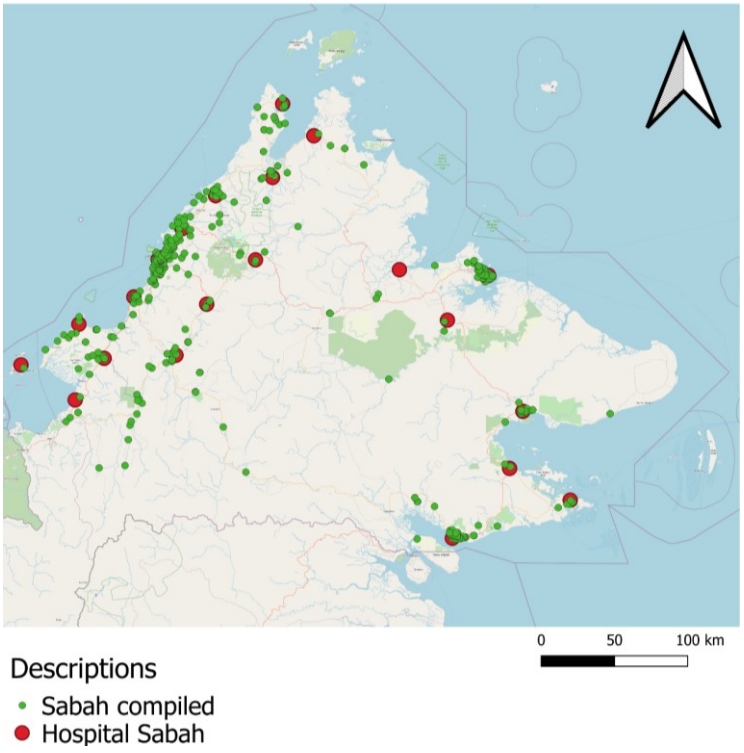
State	**Total patients**	**Obtainable Coordinates**	**Unobtainable Coordinates n(%)**
Kelantan	363	350	13(3.5)
Sabah	589	517	72(12)

QGIS version 3.12.1 was used for the layering of map. The source of map was from OpenStreetMaps from QGIS. Map 1 show the distribution of patients with CRC in the state of Kelantan represented by orange dots in relation to the location of hospitals represented by red dots. Map 2 shows the distribution of patients with CRC in the state of Sabah represented by green dots in relation to the locations of hospitals in red dots. There was a total of 24 government hospitals in Sabah and 12 government hospitals in Kelantan. The dots may not represent the actual number of patients as they have been scaled down. However, with QGIS the actual representation can be visualised as the scaling be adjusted with software. Spatial global pattern analysis by average nearest neighbour was performed using ArcGIS version 10.2 and the p-value for both states were <0.01. The results from the average nearest neighbour suggest clustered pattern for both states. Given the z-score value as mentioned above both states have less than 1% likelihood that this cluster pattern could be the result of random chance (Table 4 and Figure 1).

Hotspot analysis was performed to identify the focused area on the clustered data for both states using optimised hotspot analysis in ArcGIS. It is possible that the hotspot region over the north east of Kelantan is due to high density of population (Map3), whereas in Sabah there were no specific region of hot or cold spots were identified (Map 4).



Map 1: Distribution of patients with colon and rectal cancer in the state of Kelantanin relation to hospitals

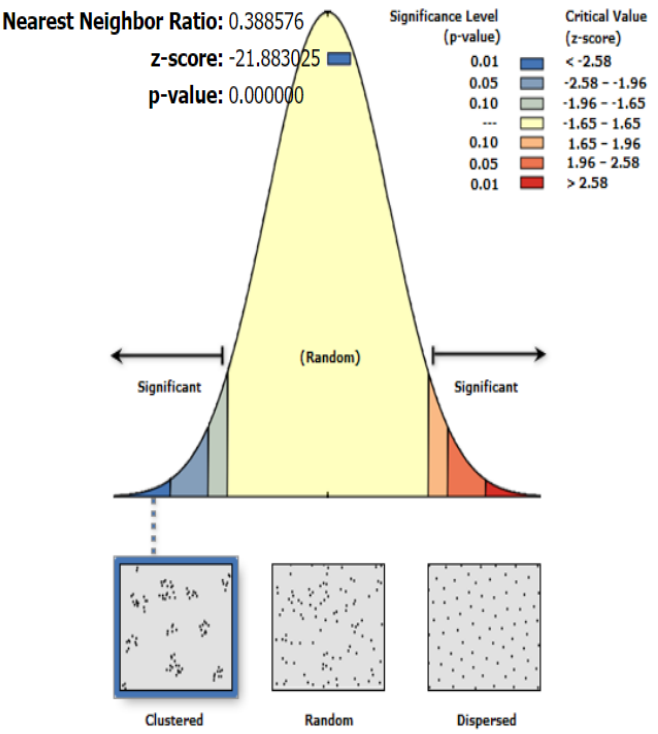


Map 2: Distribution of patients with colon and rectal cancer in the State of Sabah in relation to hospitals

Table 4: Average nearest neighbour summary for Kelantan and Sabah

State	Nearest Neighbour Ratio	Z-score	p-value	pattern
Kelantan	0.38	-21.88	<0.01	Clustered
Sabah	0.27	-31.17	<0.01	Clustered

a)



b)

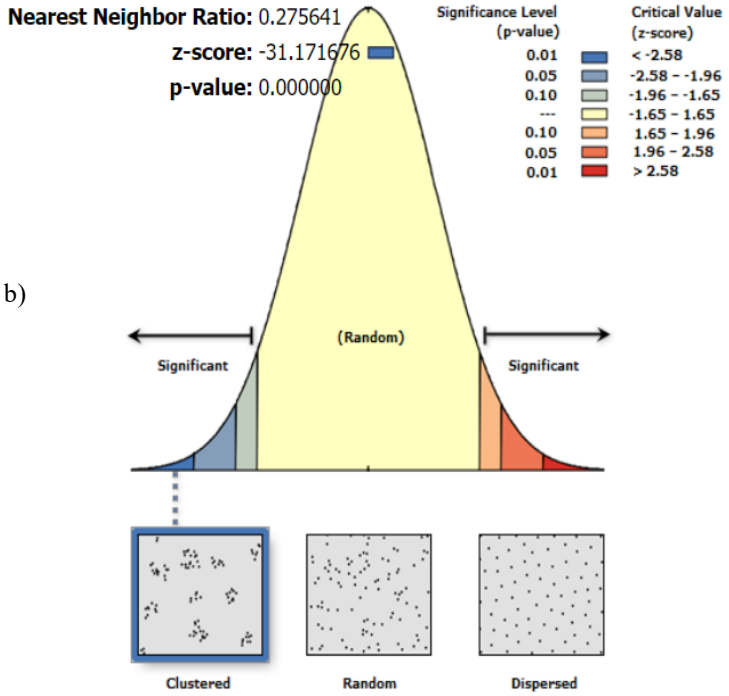
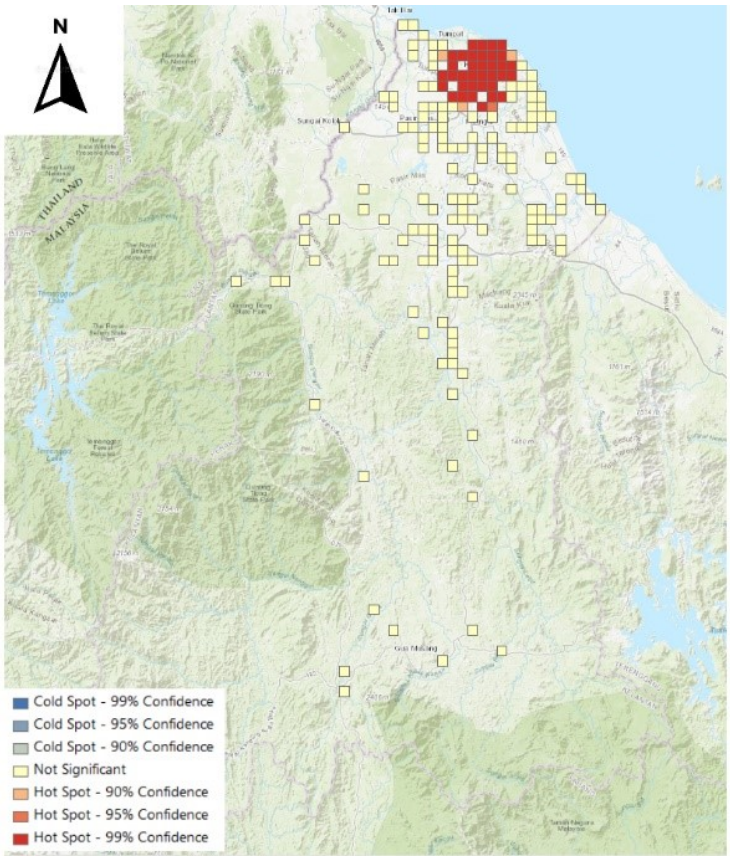
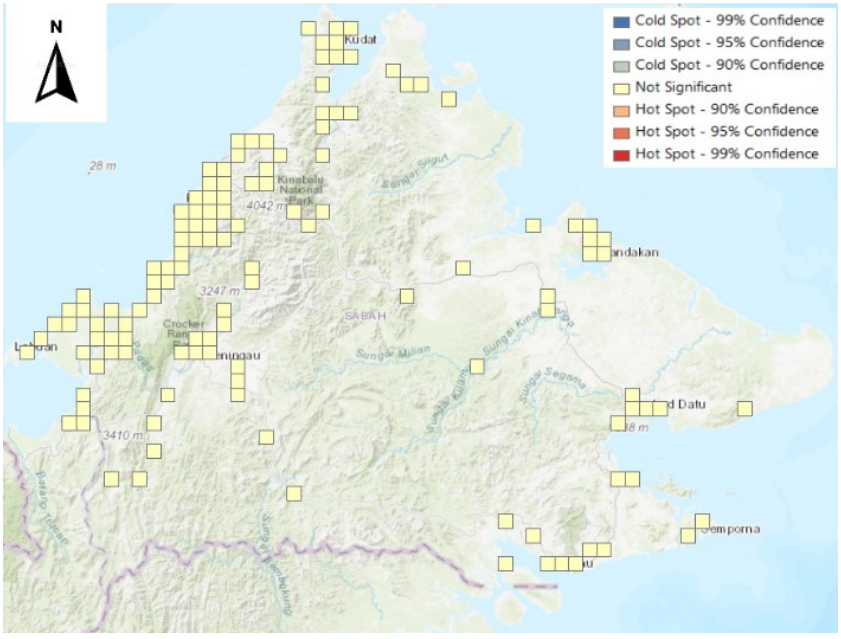


Figure 1: a) Average nearest neighbour summary for Kelantan and figure, b) Average nearest neighbour summary for Sabah



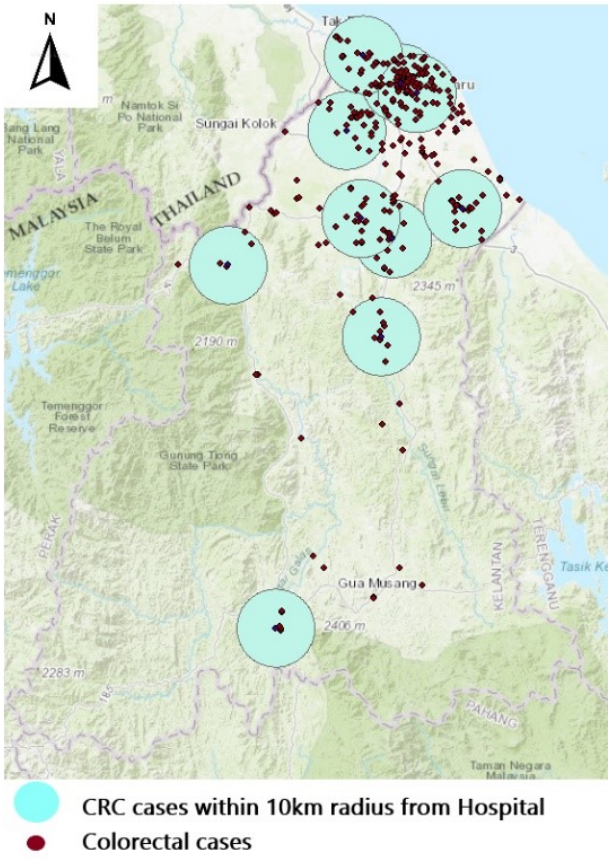
Map 3: Hotspot analysis for Kelantan



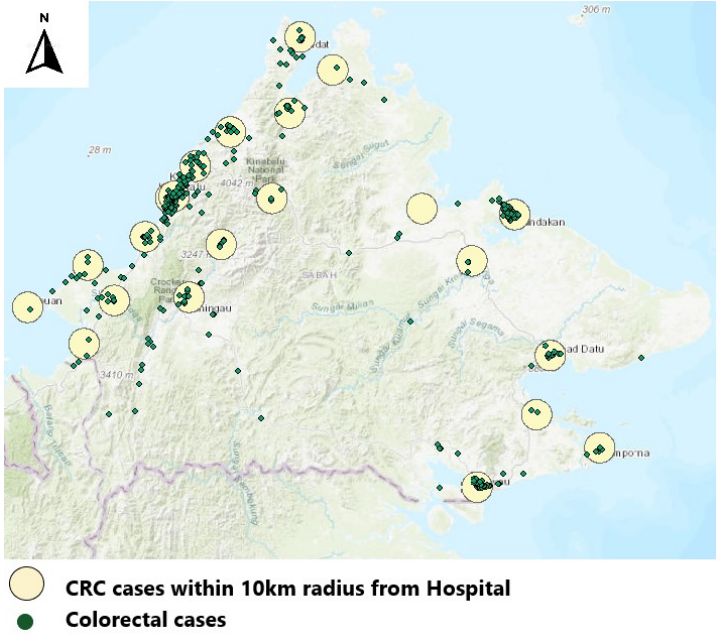
Map 4: Hotspot analysis for Sabah

In accordance to the spatial analysis, both states have patients with CRC who need to travel more than 10km to reach the nearest hospital (Map5). This situation is more apparent in Sabah than Kelantan which suggest that government healthcare facility for screening or follow up for CRC is less accessible. Further analysis with buffer showed 154 patients in Kelantan and 127 patients in Sabah

which were situated within 10km radius of 2 or more hospitals (Map 6). These mostly consist of patients in Kota Bharu in which Hospital Raja Perempuan Zainab II and Hospital Universiti Sains Malaysia is situated in close proximity. Likewise, in Sabah Hospital Queen Elizabeth 1 and Hospital Queen Elizabeth 2 are situated within 10 km radius of each other.



Map 5: CRC cases within 10km radius of the nearest hospitals in Kelantan



Map 6: CRC cases within 10km radius of the nearest hospitals in Sabah

4. Discussion

In 2017, there were 1.8million incidence of colorectal cancers cases and 896000 deaths globally with an age-standardised death rate of 11.5 per 100000 person-year (Safiri et al., 2019). The Malaysian National Cancer Registry Report (MNCR) 2012-2016 (Azizah et al., 2016) has ranked CRC to be the commonest cancer amongst male and second highest amongst female. A total of 15 515 cases of CRC were registered between the year 2012-2016. This number has been on the increase compared to previous years. The lifetime risk of males to develop CRC is 1 in 55, where else in females its 1 in 76. The lifetime risk to develop CRC was higher for the Chinese which was 1 in 43 in males and 1 in 57 among females. The incidence increased with age and peak incidence was at 70. MNCR (Azizah et al., 2016) also reported that majority of the population with CRC was detected at late stage (stage III and IV) which was also higher than the previous years. This was similarly represented by our study which showed more than half of the patients diagnosed with CRC are stage III and IV, 56.8% from Sabah and 55.4% from Kelantan. The average age of cases with CRC in Sabah is lower than Kelantan which is between 51-60 years old. The Chinese in Sabah represented the highest percentage of CRC cases despite only accounting for 12.8% of the papulation. However, Malays represent most cases in Kelantan as there were only 3.4% of Chinese population in the state.

Public health has utilised Geographic Information Systems (GIS) to compare data related to disease in a particular area in the last 150 years. Environmental and spatial characteristics were found to have influence in the spread of diseases such as cholerae and dengue. (Samad et al., 2010). A study by Ahmad et al, GIS showed its use as a tool for analysis and solving problems in health care sector (Ahmad et al., 2015). The system was used to analyse relationship between dengue disease and climate factors in Cheras, Malaysia. Records from the National Cancer Registry of Malaysia are usually presented in a tabular form. This format provides statistical data but lacks the spatial component which limits the use of GIS to analyse CRC cases. In this study, we used GIS to identify the distribution of patients with CRC and existing government hospitals in Kelantan and Sabah. We also performed spatial analysis to identify if the data has a clustering nature in accordance to p-value and z-score. In pattern analysis tool, the p value represents the probability that the observed spatial patterns were created by random process. A small p value suggests that a random process for pattern analysis is less likely. On the other hand, Z-score represent the standard deviation. Comparison of the p value and z-score suggest our cases of colorectal cancer to be clustered. In study by Shah et al, spatial analysis of CRC in Kuala Lumpur showed similar cluster results (Shah et al., 2014). The probable cause for clustering which includes dietary and environmental factors may require further investigations.

In a study from Netherlands by Elferink et al, demonstrated spatial variations in stage specific cancer incidence (Elferink et al., 2012). This was a potential guide for policy makers in planning of healthcare facilities and local educational interventions. According to Department of Statistics Malaysia (2019), Kelantan has a population of 1.89 million in an area spanning 15040km2 and Sabah has a population of 3.9 million in an area spanning 73904km2. Large area with difficult accessibility to rural population proves Sabah to be challenging for healthcare providers to screen for CRC in comparison to Kelantan.

There are 24 government hospitals in Sabah and 10 in Kelantan however, not all of these hospitals are able to support screening and follow up for CRC patients. The data provided in this study may potentially be a guide to target specific clusters of CRC in both Kelantan and Sabah, thus enhancing CRC screening. As a preventive approach, the hotspot analysis data in Kelantan can be used for better screening and public education of the disease. Although, Sabah did not have specific hotspots, there were certain region with CRC cases which are far from the nearest hospitals. For example, Nabawan, Tenom, and Telupit. The Surgical team from Queen Elizabeth 1 Hospital, have routinely performed district visits to perform colonoscopy using a portable device for both screening and surveillance purposes. This study may potentially guide the team to target districts which may require improved screening and public education efforts.

A new global collaborative effort by Knight et al, elaborated on early cancer outcome for countries with upper middle income were poorer than high income countries which showed a higher 30 day postoperative mortality (Knight et al., 2021). The study showed that poor access to postoperative monitoring, critical care facility and emergent imaging were among the contributing factors in an insufficient capacity of rescue after major complications. In a study by Ghazali et al which investigated on survival model of colorectal cancer in Malaysia and incorporated geographical location found spatial variations in survival prognosis for CRC cases in Malaysia (Ghazali et al., 2021). A systemic review by Manser and Bauerfeind found socioeconomic status and accessibility to healthcare

centres were crucial to survival outcome for patients with CRC, where the risk of death were greater amongst the low socioeconomic index group (Manser and Bauerfeind, 2014). Our analysis has showed both states to have CRC cases which require them to travel more than 10km to reach the nearest government healthcare hospital. Sabah is more severely affected than Kelantan as there were more CRC cases which requires patients to travel further than Kelantan. Furthermore, Sabah is burdened by natural barriers such as lush forest and its inaccessibility.

Recent findings by (Safiri et al.,2019) after analyzing the attributable risk factors of CRC in 195 countries found that diet in low calcium, alcohol use and diet low in milk are among the highest percentage of attributable risk factors for both genders. However, the highest percentage of global attributable risk factors between the age of 55-59 years old were from alcohol use, 65-69 years of age were smoking and 85-89 were from high fasting plasma glucose levels for both genders. The risk factors for the Sabahans to develop CRC at a younger age group than Kelantan requires further investigations. In a study by (Meaner et al., 2015), globally nearly 5 billion people lack access to safe, affordable surgical and anaesthesia care when needed and proper planning is required to address this issue. GIS has proved to be valuable modality for healthcare services and community organizations to define area with greatest need, (Lofters et al., 2013). Our study can be beneficial to stake holders and policy makers by improving the public awareness to prevent late detection of CRC. In our data, most of the CRC cases from both states were from advanced stage (Stage III and Stage IV). This indirectly reduces the cost of providing healthcare services to those population.

5. Conclusion and Recommendations

Approximately a quarter of the CRC cases from both states did not have staging of cancer specified. Some of which did not have proper residential addresses. Although the socio-economical background could be a possible cause, emphasis on data reporting and procurement should be stringent. A specific demographic study may be required to evaluate the possible cause of such issues for both states. Environmental risk factors were not included in the geographical spatial analysis for this study. Furthermore, dietary habits and other habitual risk factors were not incorporated. We recommend a larger case control study to include environmental, dietary, and habitual risk factors to fully gauge the causative factors of the clustering of CRC cases in both states.

GIS provides an alternative method of data analysis in comparison to tabular form for CRC cases in Kelantan and Sabah. These results can be potentially used to improve screening of CRC in both states by assisting in providing targeted screening and improve population awareness of the disease. Early detection of CRC may improve the overall survival for the patient and reduce the burden on government healthcare facilities by providing early intervention. It is crucial for us to further explore the multiple factors including environmental factors which may contribute to the occurrences of CRC in Malaysia.

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