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Spatial Distribution of Breast and Cervical Cancer Incidences in Kelantan: A Geographical Analysis

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ABSTRACT: Breast and Cervical Cancers are globally the two most common cancers among women. In Malaysia, 3,738 and 1,557 breast and cervical cancer cases were reported in 2003 respectively. At present, detected cases are recorded and stored in tabular form, which can only be used to present the statistics of the cases. It lacks the spatial component which could be used not only to evaluate the statistics, but also to show the location (place), distribution and pattern of cases. This study demonstrates the application of spatial statistics methods in mapping and evaluating the spatial distribution of breast and cervical cancer incidences in the state of Kelantan. The analyses show that both incidences are clustered mainly in Kota Bharu district. This is probably due to the high concentration of population in this district, and the population's accessibility to screening and health care facilities. The study provides an alternative approach to view health data and advocates the inclusion of spatial information in the Cancer Registry. This information could effectively be used in communicating with, and educating the public or planning health care delivery.

Keywords: Geographic Information System, Breast Cancer, Cervical Cancer, Kelantan, Point Pattern Analysis

Introduction

Cancer is a public health problem in many countries. In 2008, for example 12.7 million cancer cases with 7.6 million deaths worldwide, where 56 % of the cases and 64% of death occurred in the developing nations (Jamel et al., 2011). According to Globocan statistics (2008) as cited in Jamel et al., (2011), breast cancer is the leading cause of cancer death with 691,300 new cases and 268,900 deaths, while cervix uteri cancer is the second common type of cancer with 453,300 new cases and 242,000 deaths in the developing nations. The increase in deaths that occurred in the developing countries was attributed to low public awareness and late diagnosis (Okobia et al., 2006; Wong et al., 2009). In Malaysia, for example, 3,738 and 1,557 cases of breast and cervical cancer were reported in 2003 respectively (Lim and Halimah, 2004). The statistics from National Cancer Registry shows an alarming rate of cancer cases in Malaysia. It is, however, viewed in tabular form which limits its ability to be analyzed spatially such as in assessing clusters of cases to look for possible aetiological factors or planning of health services for screening or treatment (Samat et al., 2010).

According to National Cancer Society (2006), 80% of cancer cases are curable if detected early. However, most cancer cases in Malaysia were detected at stage III, which makes it difficult to achieve a cure (Wong et al., 2009; Ghazali et al., 2009). This is probably due to low awareness among the population regarding cancer screening or low accessibility of the people to screening facilities (Rabeta Mohd Salleh et al., 2011). Since cancer has been a major cause of death in many countries, it is important to improve population health by evaluating the spatial differences in the distribution of cancer cases, mapping possible clusters of cases, identifying possible aetiological factors, and addressing strategies to improve health facilities (Rushton, 2007; Murad, 2007). In Malaysia, the National Cancer Registry was set up in 2002 (Kelantan Cancer Registry, 2006). At present detected cases are recorded, stored and published in tabular formats. It lacks the spatial component which could be used not only to evaluate the statistics, but also to show the location (place), distribution and pattern of cases.

Geographical Information Systems (GIS) have been widely used in many developed countries to map health related events and the results are used for planning of health services (such as locating screening centres) as well as in assessing clusters of cases to look for possible aetiological factors. In the United States in particular, cancer cases notified to registries are routinely entered into GIS, thus monitoring trends and evaluating patterns of diseases could easily done over time. For example, the study by Rushton (2007) demonstrated the application of GIS in mapping cancer burdens on population in Iowa State. By incorporating geographic component in the analysis, it could be used in spatial allocation of resources, identification of areas with higher than expected incidence rates (disease clusters) and optimal location of resources (Levine et al., 2009; Samat et al., 2010).

Similarly, Moore and Carpenter (1999) demonstrated various applications available in GIS that could be used in detecting clusters of disease, mapping disease, and investigating diffussion of disease. The incorporation of GIS on those analysis allowed for quick comparison of data, reclassification, manipulation and analysis of case distributions. Furthermore, analyzing pattern of disease will provide useful insight to health data which can be viewed from multiple approaches, thus, giving new outlooks into the issue (Rushton, 2007; Moore and Carpenter, 1999). GIS provides the opportunity to revisit traditional methods of analysis through the use of spatial data integration and innovative graphics which might be useful for planners and decision makers in planning and evaluating the location of health facilities in the region (Samat et al., 2010).

Apart from using GIS to handle spatial distribution of cases, spatial statistics could effectively be used to understand the clustering of cases such that appropriate action could be undertaken to help the patients. Spatial statistics comprise a set of techniques to describe and model spatial data. It has the capability to assess spatial patterns, distributions, trends, processes and relationships. As opposed to the traditional (non-spatial) statistical techniques, spatial statistical techniques actually employ space area, length, proximity, orientation or spatial relationships directly in their mathematics (Robinson, 1998; Scott and Getis 2008). With these attributes, spatial statistics are more powerful in dealing with spatial data. Many studies have optimised the strength of spatial statistics. For example, this technique had been applied to determine the disease outbreaks, build a highway, plan a city and many more (Taher Buyong, 2006). Furthermore, spatial statistics provide useful tools to describe and analyse how various geographics objects (or events) occur or changes across the study area and over time. These statistics are formulated specifically to take into account the locational attributes of the geographic objects. Spatial statistics can be used to describe patterns formed by geographic objects in one study area and compare them with patterns found in other study areas (Wong and Lee, 2005).

Spatial distribution of cancer type, which can be identified as dispersed, random or clustered could provide useful insight on general location of the cases (Rushton, 2007; Samat, et al., 2010). The rationale behind this analysis is based on Tobler's First Law of Geography, *"Everything is related to everything else, but near things are more related than distant things*", such that similar objects that are related to each other will create clustered pattern, whereas different objects will create dispersed pattern (Robinson, 1998; Taher Buyung, 2006). Moreover, the random patterns, however, shows that they have mix of similar and dissimilar objects in the identified area (**FIGURE 1**).

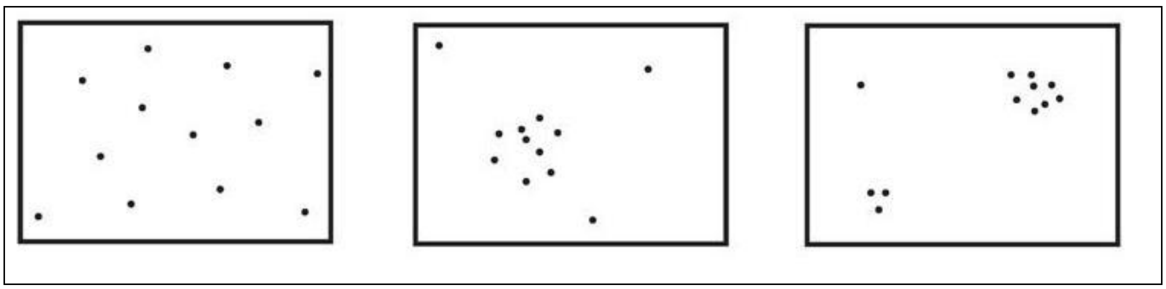

FIGURE 1: The type of dispersed, random and clustered pattern
Source: Robinson (1998)

In addition , measures of central tendency could be used to visually identify locational information of the distribution. It could be used to easily spot the concentration of the cases. This study employed the spatial statictics approach to visualize and evaluate the data.

Methodology

Information on spatial distribution of cancer cases would be useful for planners and health practitioners to evaluate the clustering of cases and help identify the geographical areas that have unusual patterns of distribution as well as those that require more screening or treatment services. At present, addresses of the patients are available but are kept with the patient's record. Without using this data, it would be difficult to visualize areas that are most in need of new health facilities. This studyattempted to map the distribution of breast and cervical cancer cases in Kelantan State. The study began by getting Ethical Approval from the Research Ethics Committee (Human) of Universiti Sains Malaysia which is in compliance with ICH GCP guidelines (USMKK/PPP/JEPM[204.3 (8)]). This study was also registered with the National Medical Research Register (NMRR-08-1336-2734).

The location of cancer patients were identified based on addresses gathered from patients' record University Sains Malaysia Hospital (HUSM) and geographic coordinates were captured using Global Positioning System (GPS). The original data was obtained in EXCEL format. In order to correctly locate the recorded addresses, Google Earth software, postmen and help from the local people were used. No contact was made with the patients and addresses were not verified with the owner of the houses. The data were entered into ArcView 3.2 and converted into ArcGIS 9.2 format. The entered data were verified with the patients' file records at HUSM. There were 186 and 159 confirmed and verified breast and cervical cancer cases respectively. This data were transferred into ArcGIS 9.3 software for further analysis. Spatial distributions of the cancer cases were measured and assessed. The distribution of breast and cervical cases were analyzed using Global Average Nearest-Neighbour Distance (ANN). In addition, statistical techniques namely mean center and standard deviational ellipse were used to measure central tendency of each cancer type. The tools can be found in the ArcToolBox in ArcGIS 9.3.

Point pattern analysis was conducted to evaluate the distribution of breast cancer and cervical cancer cases in Kelantan state. Average nearest neighbor index (NNI) could be calculated using equation 1 below.

$$NNI = \frac{d(NN)}{d(ran)} \quad \ldots\ldots(1)$$

Where;

NNI = the ratio of observed nearest neighbor distance to the mean random distance

d(NN) = the distance between each point and its nearest neighbor

d(ran) = expected nearest neighbor distance, based on completely random distribution

$$d(NN) = \sum_{i=1}^{N}\left[\frac{Min(d_{i,j})}{N}\right] \quad \ldots\ldots(2)$$

where ;

d(NN) = nearest neighbor distance

$Min(d_{i,j})$ = the distance between each point and its nearest neighbor

N = the number of point s in the distribution.

$$d(ran) = 0.5\sqrt{A/N} \quad \ldots\ldots(3)$$

where;

d(ran) = mean random distance

A = the area of the region

NNI values range from 0 to 2.1491, where the value of 0 indicates that the distribution as clustered, the value of 1 the distribution as random and the value of 2.1491 indicates that the distribution is perfectly uniform (Robinson, 1998).

The measure of central tendency was calculated by computing the geometric center – the average *X* and average *Y* coordinate – for a set of geographic features. It is commonly used to compare distributions of different types of features or to find the center of features based on an attribute value.

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}, \overline{Y} = \frac{\sum_{i=1}^{n} y_i}{n} \quad \text{……………………………………………………..(4).}$$

Where;

$\overline{X}$ and $\overline{Y}$ = the coordinates of the mean center;

x_i and y_i = the coordinates of point *i*, and

n = the number of points.

Finally, the spatial direction distribution or standard deviational ellipse was generated. This measures the spatial distribution of geographic features around their geometric center, and provides information about the dispersion in terms of compactness and orientation (Taher Buyung, 2006). It can capture the directional bias in a point distribution. Three components are needed to describe and define a standard deviational ellipse: an angle of rotation, deviation along the major axis (the longer axis), and deviation along the minor axis (the shorter axis). If the set of points exhibits a certain directional bias, then the direction with the maximum spread of the points can be identified. The mathematical equation of standard deviational ellipse is given as:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n}}$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{Y})^2}{n}} \quad \text{……………………………………………………..(5)}$$

Where;

x_i *and* y_i = the coordinates for feature i;

$\overline{X}$, $\overline{Y}$ = the Mean Center for the features, and;

n = the total number of features

The analysis was undertaken using ArcGIS 9.3 software (ESRI, 2006).

Study Area

TheKelantan Cancer Registry was started in 1998, the present centre was setup in 2002 to be one of the main sources of clear and high quality cancer data for Kelantan state (Kelantan Cancer Registry - KCR, 2006). For this study, however,it was decided to get cancer patients' home addresses from the case records as it has been found that the address information in other cancer registries were incomplete for accurate localisation (Samat et al., 2010).

The population of Kelantan state is 1,539,601 and 95.7% are Malays, 3.4% Chinese, 0.3% Indians and 0.6% others (Department of Statistics, 2010). Kota Bharu is a highly populated district accommodating 30% of the total population in Kelantan. Kelantan is located on the north-eastern part of Peninsular Malaysia (**FIGURE 2**). Mapping the two cancer types in Kelantan using GIS is an advantage as this allows the analysis of the pattern of the two diseases and could potentially lead to discovering the characteristics of each cancer type. This can indicate potential aetiological factors as well as be useful for planning of prevention programmes.

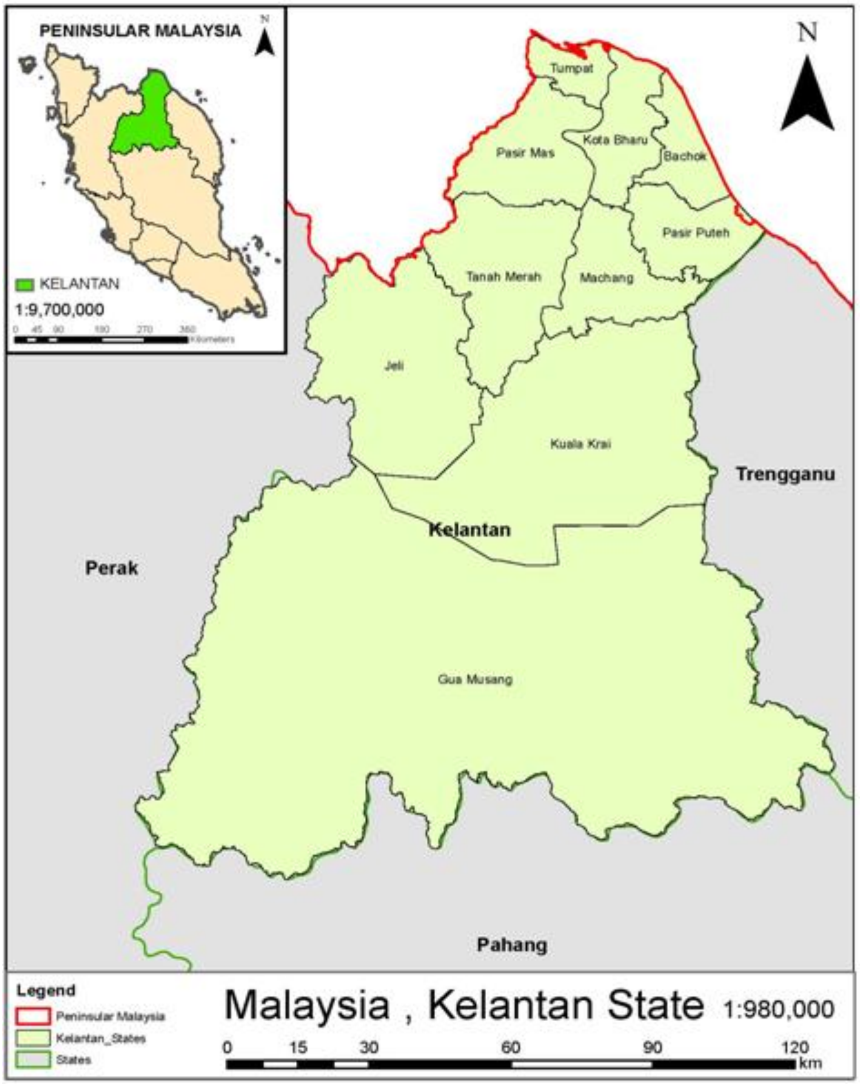

FIGURE 2: The study area

Spatial Distribution of Breast and Cervical Cancer Cases in Kelantan State

There were 186 and 159 breast cancer and cervical cancer cases recorded and mapped from HUSM respectively (**FIGURE 3**). The distribution of breast and cervical cancer cases in Kelantan is clustered. NNI calculated for breast and cervical cancer cases are 0.49 and 0.52 respectively. Few clusters of cases can be detected. The cluster of breast cancer cases could be seen in Kota Bharu. However, only few cases were located close together within Tanah Merah, Pasir Mas and Tumpat. Further analysis could be undertaken by calculating NNI for each district in order to detect possible cluster for each district. Suprisingly, for cervical cancer cases, cluster of cases were detected in all the afore mentioned areas of Kota Bharu, Tanah Merah, Pasir Mas and Tumpat. Similarly, calculating NNI for each district probably would reveal different pattern of distribution. **TABLE 1** shows the number of cases for each districts. This pattern probably follows spatial distribution of population for the state.

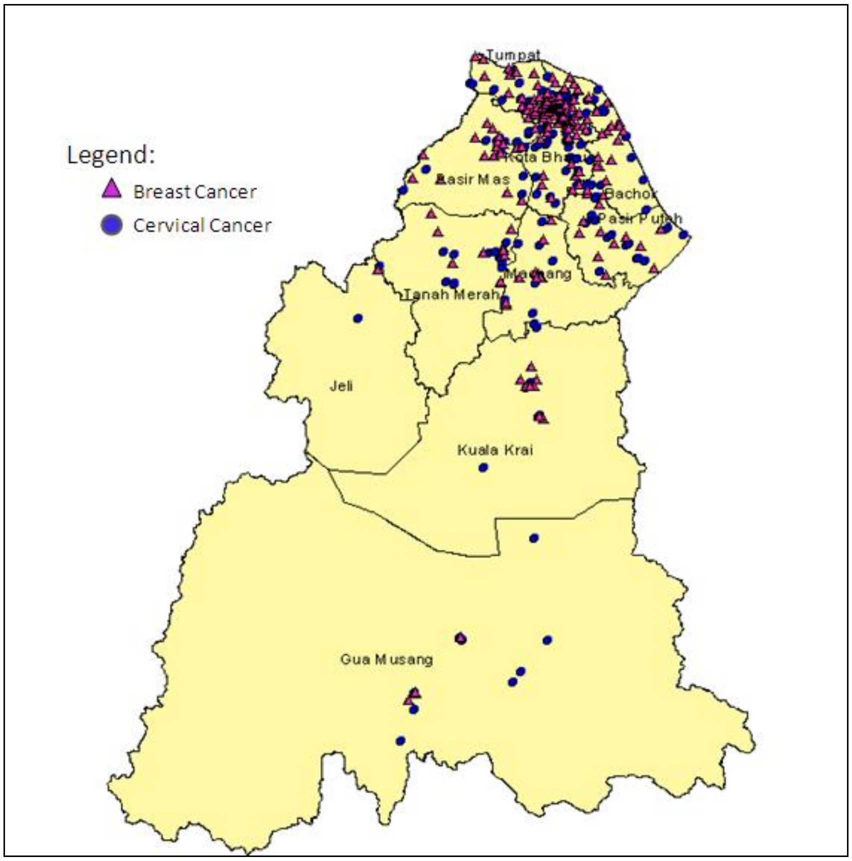

FIGURE 3: Spatial distribution of breast and cervical cancer cases in Kelantan

TABLE 1: Total number of cases for each district in Kelantan

District	**Breast Cancer**	**Cervical Cancer**
Bachok	17	20
Gua Musang	7	8
Jeli	2	1
Kota Bharu	93	65
Kuala Krai	2	8
Machang	11	6
Pasir Mas	18	14
Pasir Puteh	9	12
Tanah Merah	9	10
Tumpat	18	15
Total	186	159

The study, then, calculated mean centers for breast and cervical cancer cases. Mean centres of the distribution for both cancer cases were also located in Kota Bharu (see **FIGURE 4** below). It illustrates that most of the cases were distributed in close proximity to Kota Bharu. Although most of the cases were found surrounding this region, attention should also be given to other areas in planning health care delivery in other districts in Kelantan. In addition to calculating central tendency of the cases, this study also measures the spatial direction distribution or standard deviational ellipse, which shows feature dispersion in terms of compactness and orientation of the cases (Wong and Lee, 2001; Taher Buyung, 2006). In **FIGURE 5** shows the breast (left) and cervical (right) cancer cases seem to have similar spatial direction in terms of distribution. The two types of cancer spatial direction concentrated at the north of Kelantan state which also focuses on Kota Bahru district. The findings also show that the both type of cancer cases studied occurred mostly in high populated area. Suprisingly, the direction of the ellipses were almost identical except the major axis for cervical cancer cases was slightly longer than that for breast cancer cases. Further study could be undertaken on tyring to correlate the two type of cancer cases.

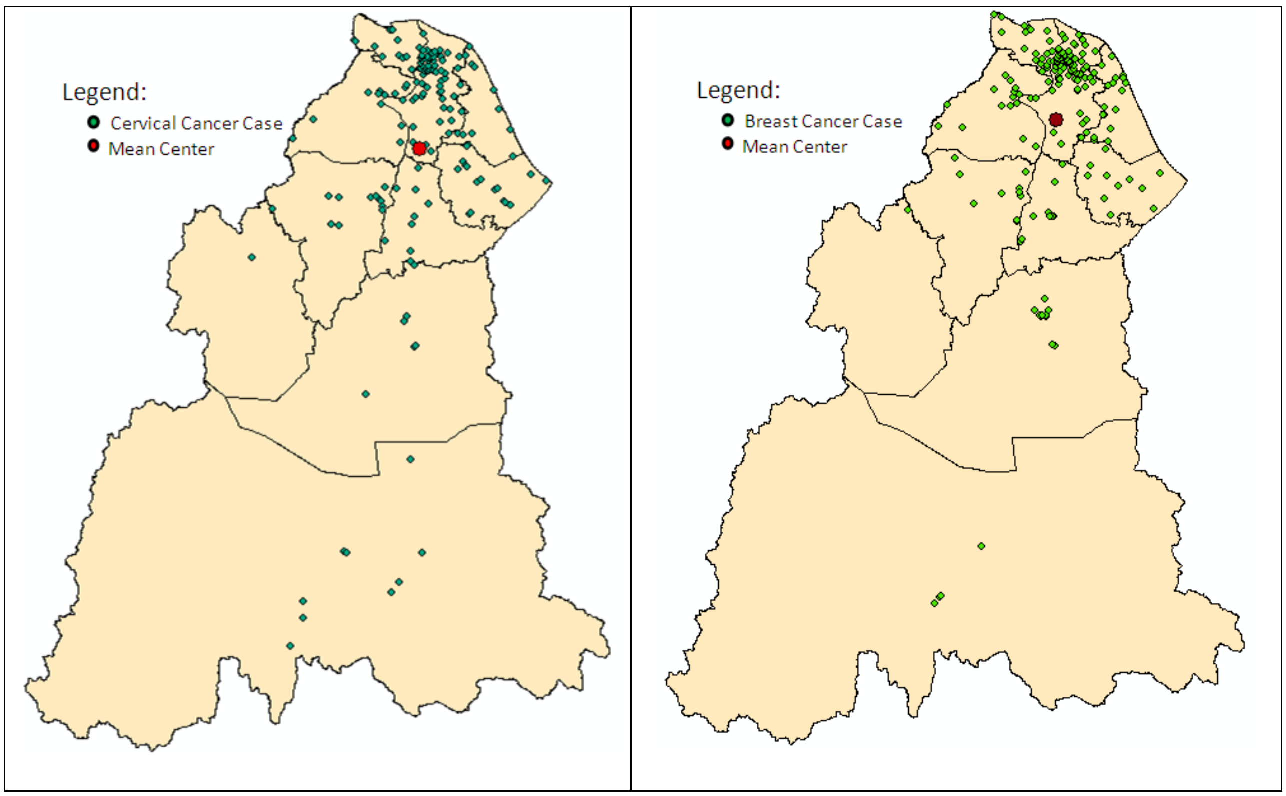

FIGURE 4: Spatial distribution and mean centre for breast (left) and cervical (right) cancer cases in Kelantan

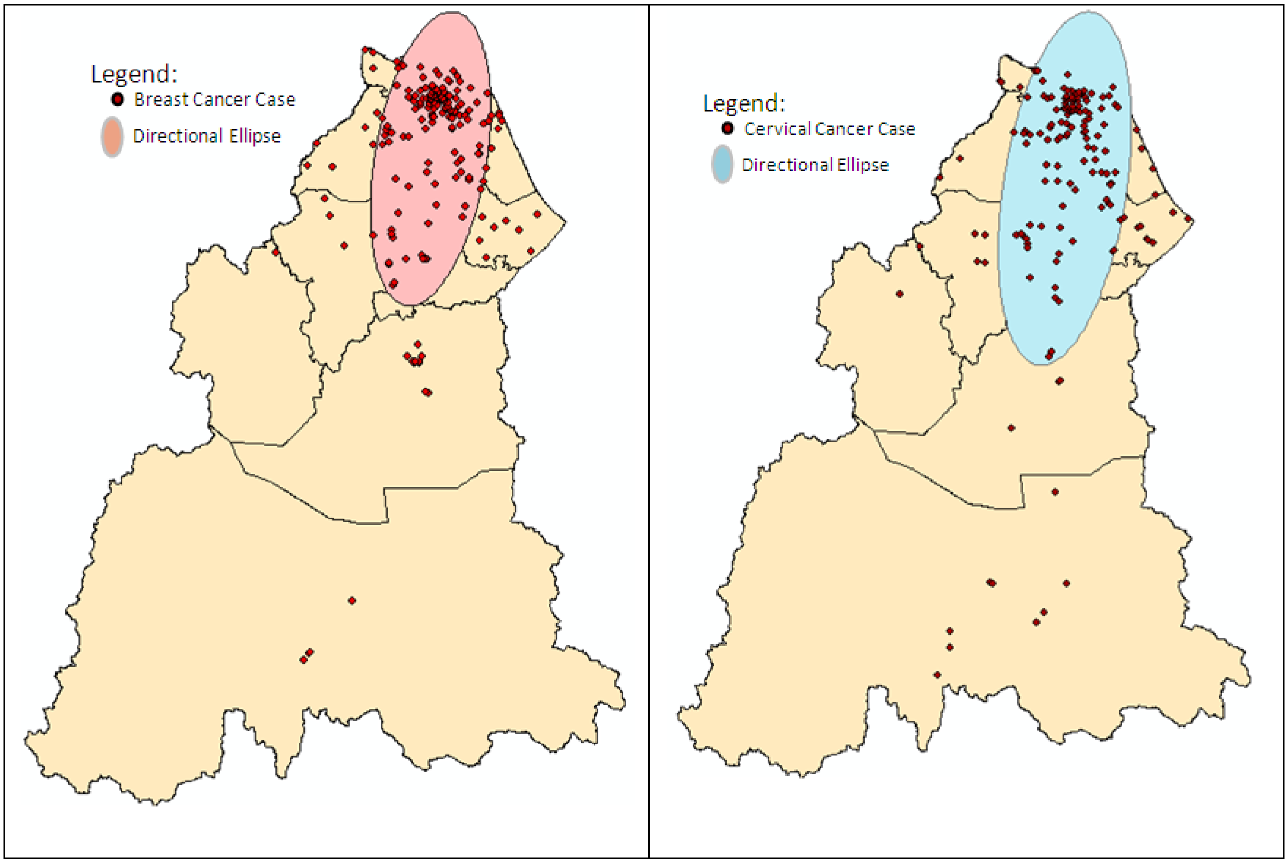

FIGURE 5: Spatial distribution of breast (left) and cervical (right) cancer cases in Kelantan

Discussion

The use of GIS in mapping the distribution of breast and cervical cancer cases provides analytical capability to appreciate the factors causing non-uniformity of cases distribution. It should be noted, however, at present the analysis was undertaken without taking into account the population spatial distribution. Further analysis will be undertaken to consider population distribution such that we do not have to worry about the influence on clustering by population density. This is crucial in looking for aetiological factors . However, the result obtained from the analysis undertaken in this paper could be useful for planning and accessing health care delivery for the state. In addition, further study could be undertaken to relate the location of cases with factors such as physical and environmental factors, socio-economic factors, and genetic factors (Moore and Carpenter, 1999). Human body is sensitive to many environmental poisons and elements. Potentially once population density is accounted for, using GIS in mapping and correlating health and biological hazards can be done in order to generate risk map such that vulnerable areas for breast or cervical cancer could be identified. Moreover, methodologies and techniques of using geographical locations, therefore, could help in research discoveries and in health care delivery (Maantay, 2002).

Mapping and investigating spatial distribution of breast and cervical cancer cases from multiple approaches would give new outlooks into the issue (Moore and Carpenter, 1999; Rushton, 2007). GIS provides the opportunity to understand geographic variation of the cases distribution and identify possible cluster of cases (Samat, et al., 2010). Moreover, further study could be undertaken to evaluate the accessibility of cases to hospitals that provide screening and treatment for patients. According to Jordon et al., (2004) the ideal distance between health facilities and cancer patients should be less than 12 kilometres or approximate 20 minutes driving time at at medium speed. This will reduce the burden of patients enduring pain during the travelling as well as limiting the cost of the journeys. Distance from hospital or treatment centre has been reported as a significant factor associated with compliance to treatment for a number of other diseases.

Furthermore, improved accessibility to screening centers will be beneficial to the public since it can help in early detection of cases. According to the finding by Ghazali et al (2009) revealed that most of the cases in the Northern region of Peninsular Malaysia was detected at stage III and IVmaking it difficult to achieve a cure. Further studies should be undertaken to evaluate the relationship between screening behavior and the accessibility of cases to the screening centres.

Conclusion

This study mapped breast and cervical cancer cases whose addresses were obtained from patients' records at HUSM. GIS was used to map and detect spatial distribution of the cases. A few clusters of breast and cervical cancer cases were detected in Kota Bharu, Tumpat, Pasir Mas and Tanah Merah. The cases that were clustered in Kota Bharu district was probably due to the concentration of population. This limits the use of GIS to look for aetiological factors unless the spatial distribution of the population is taken into account. GIS, however, provides useful insight to health data which could be used in planning health care delivery within the state. Further analysis could be undertaken to identify areas that are in need of cancer screening and treatment facilities.

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