Small area variations of cancer mortality in Hong Kong – the roles of health care and socio-economic status[*]

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Variations of cancer incidence and cancer mortality across small areas in Hong Kong were explored and attempt made to link them to socio-economic differences. The entire Hong Kong population during the period 1984–88 was divided into 65 small areas. The geographic distributions of incidence and mortality for ten most frequent sites of cancers (6 male and 4 female) were analyzed by separating the systematic variance from the random variance. A Poisson regression model was fitted for each cancer using the standardized incidence ratio (SIR) as a covariate for mortality. The geographic variations in SIR for the individual cancers were, in turn, analyzed similarly using a socio-economic score as the covariate. We found a statistically significant systematic variance in mortality for all six male cancers and three of the four female cancers studied. More than 50% of the systematic variance of mortality for nine cancers could be explained by the geographic variations in incidence, suggesting that other factors, like the provision and/or outcomes of health care services, played a minor role. There were statistically significant systematic variances in SIR for all male and female cancers. The socio-economic score accounted for over 50% of the systematic variance for three cancer sites. This study illustrated an approach to explore underlying explanations for the geographic variations of disease incidence and mortality. As more aggregate exposure data become available at the small area level, this type of ecological analysis would help in delineating the contributions of various factors and guide investigators in their search for the etiology background of diseases.

Key words: cancer mortality, cancer incidence, geographic variation, socio-economic factors, epidemiology

Variations in the mortalities of 'avoidable' diseases across geographical areas and over time have been widely reported in the 1980s [2, 4, 14, 18, 19]. Since the publication of the atlas of avoidable mortality in the European Community [7, 8], a number of explanatory analyses from different countries have been reported [6, 15, 17, 23, 24]. The geographical variations in mortalities from the 'avoidable' diseases can be utilized for assessing the outcome of health care at the population level [14].

Studies conducted in Sweden showed that variations in cancer mortality across small geographic areas were not random, with some cancers having large systematic variations [25, 26]. The systematic variations of some cancer mortalities (e.g. lung cancer) were closely related to the variations in the corresponding incidence rates. When the variations in the incidence rates could not fully explain the variations in death rates, other explanations, e.g. differences in medical care, should be sought.

In Hong Kong, an atlas of disease mortalities was published in 1996 [12] showing wide geographic variations in mortalities from 15 diseases (including 9 cancers) across 65 small areas. It is important to elucidate whether the variations were systematic, and if so, how much of the variations were attributable to the geographic variations in the incidence rates of these diseases. When analyzed with socio-economic data, it was possible to look into geographic inequalities in health and health care. The objectives of this study are to examine the systematic and random variances in the geographic distribution of the incidences and mortalities of most frequent sites of cancer, and the role of socio-economic status in explaining the variances.

Material and methods

Cancer incidence and mortality in the period 1984–88 in Hong Kong was analyzed. The death and demographic data were obtained from the Census and Statistics Department of Hong Kong. Cancer incidence data were obtained from the Hong Kong Cancer Registry. Registered cases without known addresses were traced to their original sources, including hospitals and pathology laboratories. Both the causes of death and diagnoses of new cases were coded according to the 9th Revision of the International Classification of Diseases (ICD-9).

Hong Kong was divided into 65 smaller areas, which were amalgamated from more than 200 Tertiary Planning Units (TPUs) to ensure that a large enough population was available in each area for statistical analyses [12]. The TPU is the smallest geographic unit identifiable from the death data as well as the socio-economic data obtained from the 1986 by-census [3]. An index - F score was used as an indicator of the socio-economic status for each small area. This was derived by factor analysis [10, 12, 13] from six highly correlated socio-economic parameters of the individual areas including the percentages of residents: with higher incomes, with lower incomes, with tertiary and higher education, with lower primary schooling, as production workers and as administrative and professional workers. The higher the F-score, the more affluent the area was.

The standardized mortality ratio (SMR) and standardized incidence ratio (SIR) for each area were calculated by indirect standardization using the age-sex-specific mortality or incidence rates of the total Hong Kong population in the same period.

Statistical methods and procedures:

1. To test whether the SMRs or SIRs were different among the 65 areas. The χ^2 test for goodness of fit with k-1 degrees of freedom (k = number of areas = 65) was performed. The expected numbers of events were derived by indirect standardization. As the χ^2 test might become invalid when the expected number of deaths was less than 5 in more than 20% of areas [1], only common cancers were included in the analyses. These included cancers of nasopharynx (ICD 147), oesophagus (ICD 150), stomach (ICD 151), colon and rectum (ICD 153-154), liver (ICD 155) and lung (ICD 162) among the males and colorectal, lung, breast (ICD 174) and liver cancers among the females.

2. To estimate the different components of the variance. When the null hypothesis in step 1 was rejected, the systematic variance of the rates was estimated after accounting for the random (due to chance) variance. According to the method proposed by MᴄPHERSON et al [16] and modified by WESTERLING [25, 26], the observed variance was calculated by dividing the χ^2 values by n for each disease:

$\Sigma [(o_i-e_i)^2/e_i]/n \ .... \ [1]$

where o_i and e_i were the observed and expected numbers of deaths or cases of the disease in each area respectively and n was the total number of deaths or cases for the disease, which should be equal to the sum of the expected numbers.

Formula [1] is equivalent to:

$\Sigma [e_i(o_i/e_i-1)^2]/n \ .... \ [2]$

The observed variance was equal to the variance of the ratio between the observed numbers (o_i) and the expected number (e_i) around the value 1, with the expected value (e_i) in each area as weight.

Under the null hypothesis, the mathematical expectation of χ^2 distribution is the degree of freedom of the distribution [5], and the random variance was defined as the degree of freedom of the χ^2 distribution divided by n:

$df/n = (k-1)/n \ .... \ [3]$

The observed variance consisted of two components, the random variance and the systematic variance:

Systematic variance = observed variance – random variance

$\Sigma = [(o_i-e_i)^2/e_i]/n-df/n \ ....[4]$

3. To estimate the variances after adjustment by other independent variables. Poisson regression models were used as oi had a Poisson probability distribution:

$\log(\mu_i) = X_i'b + \log (T_i) \ .... \ [5]$

where log (T_i) was used as an offset variable and in this case equals e_i; μ_i was the expectation of the observed value for the ith stratum (area); X_is represented a group of independent variables; bs were regression coefficients in the model. As SIR was considered as an explanatory factor for mortality variations, it was put into the model as an independent variable. The Pearson χ^2 value of the model would be reduced and was used to calculate the adjusted observed variance with k-2 degrees of freedom. The new χ^2 value was also used to determine if there was significant residual systematic variance after adjustment. This SIR-adjusted systematic variance could then be subtracted from the total systematic variance (from equation 4) to give the SIR-related systematic variance. The p-value of the estimate b (for SIR) was used to decide on whether the SIR-related systematic variance was significant. The same procedure was used to delineate the influence of the F-score on incidence and SIR-adjusted mortality. The calculations were performed using the Statistical Analysis System [20].

Results

Table 1 shows the crude incidence rates and crude mortality rates for the total population of Hong Kong and the ranges of SIRs and SMRs of six major cancers for males and 4 for females during 1984–88 in the 65 districts. Lung cancer had the highest incidence and mortality rates for both sexes. A wide range was present for the SIRs and SMRs of the different cancers in both sexes.

Table 1. Crude incidence rate, crude mortality rate and the range of SIRs and SMRs for different cancers in Hong Kong, 1984–88

Site of cancer	Incidence		Mortality	
	Crude rate (per 100,000)	Range of SIR in 65 areas	Crude rate (per 100,000)	Range of SMR in 65 areas
Male				
Lung	72.3	43.2–132.8	52.5	13.4–149.2
Liver	37.6	33.4–198.2	28.4	11.4–208.9
Colon/rectum	29.4	55.1–185.9	13.7	25.4–190.6
Nasopharynx	26.7	20.4–171.8	11.6	0.0–220.0
Stomach	18.2	23.4–199	10.6	0.0–171.9
Oesophagus	15.6	0.0–171.8	10.8	14.3–186.2
Female				
Lung	39.5	45.0–137.6	30.0	23.1–154.0
Breast	30.9	60.3–199.3	9.5	15.5–206.2
Colon/rectum	27.5	47.3–172.8	13.0	0.0–191.4
Liver	11.2	0.0–177.7	8.4	0.0–206.2

SMR – Standardized Mortality Ratio using the age-sex-specific mortality rates of the total population in the same period, SIR – Standardized Incidence Ratio using the age-sex-specific incidence rates of the total population in the same period.

Table 2. Systematic variances in SMR of cancers before and after adjusting by SIR in 65 areas in Hong Kong, 1984–88

Sex	Site of cancer	Before adjusting by SIR			SIR-adjusted SV in mortality	SIR-related SV in mortality	% due to SIR-related SV
		Total observed variance	Systematic variance	% due to SV			
Male							
	Lung	0.0278	0.0192***	69	0.0026	0.0166**	86
	Liver	0.0274	0.0115***	42	–0.0008	0.0115***	100&
	Colon/rectum	0.0542	0.0213***	39	0.0008	0.0205***	96
	Nasopharynx	0.0742	0.0351***	47	0.0141*	0.0210***	60
	Stomach	0.0625	0.0195**	31	–0.0059	0.0195***	100&
	Oesophagus	0.0905	0.0485***	54	0.0082	0.0403***	83
Female							
	Lung	0.0288	0.0128***	44	0.0023	0.0105***	41
	Breast	0.0756	0.0254**	34	0.0031	0.0223***	68
	Colon/rectum	0.0444	0.0077	17	–0.0061	0.0077***	100&
	Liver	0.0899	0.0328***	36	–0.0031	0.0328***	100&

SMR – Standardized Mortality Ratio, SIR – Standardized Incidence Ratio, SV – systematic variance. *p<0.05, **p<0.01, ***p<0.001. &All the systematic variance could be considered as related to the SIR as the systematic variance became negative after the adjustment.

The observed variances in cancer mortality across different areas and their different components before and after adjustment by disease incidence are shown in Table 2. The systematic variances in mortality of all six cancers for males and three of the four cancers (except colorectal cancer) for females were statistically significant before adjustment by the SIR. The proportion of observed variance attributable to the systematic variance varied from 31% to 69% for male cancers and from 17% to 44% for female cancers; it was highest for lung cancer among both male (69%) and female (44%), although the absolute systematic variances were not high.

The systematic variances in mortality were much lower after adjustment for SIR with 4 becoming negative (i.e. no more systematic variation), including stomach and liver cancers for males and colorectal and liver cancers for females. Only the one for male NPC remained statistically significant. All the SIR-related systematic variances were statistically significant and accounted for 41 to 100% of the respective total systematic variances. These results indicated that the systematic variances in mortality of all those cancers could be explained mostly by the variations in incidence. Further adjustment of the NPC mortality using F-score resulted in a residual systemic variance of 0.0099, which was not statistically significant. The systematic variance attributable to F-score was 0.0042 (0.0141 minus

Table 3. Different components of systematic variances in SIR of cancers in the 65 areas in Hong Kong, 1984–88

Site of cancer	Before adjusting by F score			F score-adjusted SV in incidence	F score-related SV in incidence	% due to F score related SV
	Total observed variance	Systematic variance	% due to SV			
Male						
Lung	0.0224	0.0162***	72	0.0080***	0.0082***	51
Liver	0.0347	0.0226***	65	0.0181***	0.0045***	20
Colon/rectum	0.0438	0.0285***	65	0.0160***	0.0125***	44
Nasopharynx	0.0352	0.0183***	52	0.0145***	0.0038***	21
Stomach	0.0552	0.0305***	55	0.0307***	0&	0&
Oesophagus	0.0681	0.0392***	58	0.0182**	0.0210***	54
Female						
Lung	0.0215	0.0095***	44	0.0096***	0&	0&
Breast	0.0584	0.0429***	73	0.0171***	0.0258***	60
Colon/rectum	0.0383	0.0210***	55	0.0161***	0.0049***	23
Liver	0.0795	0.0367***	46	0.0336***	0.0031**	8

SIR – Standardized Incidence Ratio, SV – systematic variance. *p<0.05, **p<0.01, ***p<0.001. &All the systematic variance could be considered as not related to the F score as the systematic variance became larger after the adjustment.

0.0099) and accounted for 12% of the total systematic variance.

The systematic variations of incidence in all six male cancers and four female cancers were statistically significant. Table 3 shows the systematic variances in incidence before and after adjusting by the socio-economic index (F-score). After adjustment, the systematic variances of male stomach cancers and female lung cancers were not reduced, which indicated that the geographic variations in the SIR of these two cancers were not influenced by the socio-economic status of the small areas. In contrast, socio-economic status had significant influence on the geographic distribution of the other cancers and accounting for over half of the systematic variance of oesophageal and lung cancers among males and breast cancer among females.

Discussion

By linking cancer incidence and mortality data to population and socio-economic data in 65 small areas in Hong Kong, we found significant systematic variations in the geographic distribution of SMR and SIR for almost all of the cancers studied, which meant that these variations could not be explained by chance alone. Such variations were also identified in Sweden [25, 26]. But unlike Sweden, the systematic variations in SMR of almost all cancers in Hong Kong could be explained by the variations in SIR alone. Substantial proportions of the systematic variations in SIR for many cancers were attributable to variations in socio-economic status. This quantification of the influence of socio-economic status on the geographic variations of cancer incidence in Hong Kong by apportioning the total variance has not been reported before elsewhere.

In the study of the distribution of disease mortalities over time or across geographic areas, large variations were frequently attributed to differences in the availability and provision of health services [14, 15, 19]. In this study, a large part of the systematic variances observed in the mortality of cancers could be explained by the variations in incidence. After adjusting for the geographic variations of incidence, mortalities from most cancers were fairly randomly distributed across different geographic areas in Hong Kong. This reflects, at least in part, the wide availability and affordability of health services to cancer patients, which were provided through a public-funded hospital system in Hong Kong. In England, an inverse relationship between time to hospital and admission ratio for certain diseases have been documented among various small areas [22]. As Hong Kong is a relatively small area, distance and travel time to hospitals were not as important in determining whether people sought medical care from hospitals.

For cancer of the nasopharynx, the total systematic variance was not fully explained by the variation in incidence and the SIR-adjusted systematic variance was still significant. Socio-economic status was found to be an important factor affecting the distribution. It was possible that services related to early diagnosis (by otorhinolaryngologists) or appropriate treatment (by radiotherapy) for this particular cancer were not widely available at that time and patients of lower socio-economic status or living in certain 'deprived' areas might not receive diagnosis and treatment in time. The effects of earlier diagnosis could not be separated from the effects of improved treatment by measuring incidence adjusted systematic variation in mortality alone [25, 26].

Geographic variations in cancer incidence could also be partly explained by socio-economic factors, and this has

been reported even in other countries [15]. In this study, the systematic variances of incidence in most cancers became lower after adjustment for the F-score. However, statistically significant systematic variances in the incidence of all the cancers studied were still demonstrable after adjusting for socio-economic status. This was in contrast to the absence of any marked geographical variability at small area scale for testicular and prostate cancer incidences in Britain after adjusting for socio-economic effects [9, 21]. Our findings suggested that some other factors might also affect the geographic variations of cancer incidence, especially for stomach cancer among males and lung cancer among females. Furthermore, socio-economic status is a likely surrogate for certain high-risk behaviours, such as smoking, drinking [11], poor diet and unhealthy lifestyles, and should be further investigated.

By apportioning the variances of the geographic variations of SMRs and SIRs into their constituent components, we identified the relative importance of the contributing factors. There appeared to be little inequalities in health care, but substantial inequalities in health related to socio-economic status were present. The significant residual systematic variances call for further investigations.

Future research should be directed at the residual systematic variances and the underlying risk factors associated with variations in socio-economic status. As the systematic variations of cancer mortalities depended heavily on the variations in incidence, the future focus of health services should be put on preventive programmes aiming at reducing the systematic variations of incidence.

In this study, we have illustrated an approach that can be used to explore underlying explanations for the geographic variations of disease incidence and mortalities. When more and more aggregate exposure data (such as diet, cigarette smoking, air quality) become available at the small area level, this method of ecological analysis can be extended to examine the contribution of each of these risk factors. The determination of the latter would, in turn, guide investigators in the direction of their research in elucidating the causes of diseases and mortality.

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