RESEARCH COMMUNICATION

Soil and Vegetation Characteristics of High- and Low-risk Areas of Esophageal Cancer in China

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Abstract

Objectives: The purpose of this study is to explore the relationship between esophageal cancer (EC) and soil, vegetation types as well as soil organic carbon densities (SOCD) at depths of 100cm and 20cm in China. Methods: Database of EC mortality surveyed in 1990-1992 in China was established in Excel. Digital polygon maps of study areas were created in Arc/Info 9.0 software and linked with the database. Soil and vegetation types of sampling areas were extracted from digital maps of soil types, vegetation types and distribution map of EC mortality by using overlay analysis. Mean SOCD at depths of 100cm and 20cm of these areas were calculated, and spearman correlation analysis was used to evaluate the relationship between EC mortality and SOCD. Results: Soil and vegetation types of high and low-risk areas of EC in China were different. There were both negative correlations between EC mortality and SOCD at depths of 100cm and 20cm. The correlation coefficient for men is -0.504 and -0.575 (p<0.01 respectively), for women is -0.487 and -0.526 (p<0.01 respectively). Conclusions: EC may correlate to SOCD, soil and vegetation types, which needs further studies. GIS-based spatial techniques can provide an opportunity to connect diseases with ambient environment, and lay a foundation to pursue further investigation into the environmental factors responsible for disease risk.

Key Words: Esophageal cancer - geographic information system - vegetation type - soil type/organic carbon density

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Introduction

Esophageal cancer (EC), as a common malignancy, causes high mortality and ranks as the fourth most frequent cause of cancer death in China (Zou et al., 2002). In addition, EC has a striking variation in geographical distribution in China (Kuwano et al., 2005), which covers vast territories and has complex natural environment (Lin et al., 2004). This variation might reflect the exposure to specific environmental factors, such as climate, geology, landform, soil, life style, food, drinking water, consumption of alcohol and smoking, since the geographical environments have a close relationship to endemic diseases (Lin et al., 2004; Mwanda et al., 2005). It is generally recognized that EC is the result of multiple risk factors. Known risk environmental factors for EC include lacking of fresh fruits and vegetables, nutrient and micronutrient intake, nitrosamine, smoking and alcohol consumption (Stoner and Gupta, 2001; Bosetti et al., 2000). Other risk factors for EC included obesity, consumption of preserved and pickled food, mycotoxins (on corn and wheat), very hot drinks and occupational exposures to soot, certain metal dusts, and HPV infection (Stoner and Gupta, 2001). Though the known environmental factors might play a pivotal role in the etiology of this disease, soil and vegetation, as two important and basic geologic environmental factors that affect human life, might also have close relationship with EC mortality, which has been studied rarely before. In previous study, ambient climate such as drought was also found relate to EC in China (Wu and Li, 2007). We hypothesized that soil and vegetation might be involved in the occurrence and development of this disease. Therefore, this study is to explore the relationship between EC mortality in one tenth of nationwide population sampling areas and soil, vegetation types as well as soil organic carbon densities (SOCD) at depths of 100cm and 20cm in China by using Geographic Information System (GIS).

Materials and Methods

Digital Maps

The 1: 4,000,000 digital maps of China were provided by State Bureau of Surveying and Mapping. The digital maps include layers such as national boundaries, provincial boundaries, county boundaries, residential areas, rivers, main railways and main highways. The one-tenth of population sample areas digital polygon maps were created in Arc/Info GIS software (ESRI, Inc.,

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Redlands, CA) by selecting geocode from the existing national fundamental digital maps.

Esophageal cancer mortality data

The EC mortality data was obtained from one-tenth of nationwide population cause-of-death surveys conducted in mainland China in 1990-1992. (Li and Lu, 1996; Zou et al., 2002) The sampling method introduced in the surveys was cluster random sampling with two stage, stratified sampling and equiprobability (10 percent). Firstly, the study areas were stratified by province and city. Then all the counties/cities were ordered by their mortality rate from 1970's (There were also nationwide population cause-of-death surveys conducted in mainland China in 1973-1975, which included 2489 counties/cities of the whole nation.). Finally, 10% of the total counties/cities were selected in high, medium, and low mortality levels respectively. The EC mortality of the sample areas can thus be seen to represent the mortality of the whole nation. Because of difficulties, Xinjiang, Qinghai and Tibet province were not included in the surveys and 263 areas were sampled and surveyed finally. Since some areas were sections of a county (city), we selected 237 counties (cities) for our study by summing up. Standardized EC mortality rates were computed by direct method according to 1982 Chinese population age distribution and 1976 world population age distribution standard. The EC mortality database of the sample areas was created in Microsoft Excel according to male/female. Then a GIS for EC mortality was created in Arc/Info 9.0 based on the polygon map of the sample areas through inputting the mortality data regarded the county name as linked keyword. A dispersive digital polygon map of EC mortality value was drawn with graduated symbols (Wu and Li, 2007).

Soil and vegetation type database

China's 1:4,000,000 soil spatial database-digital soil maps was published by The Institute of Soil Science, Chinese Academy of Sciences (ISSCAS) in 1996. It was digitized based on China's soil map published by ISSCAS in 1978. Albers Equal Area Conic was used as projection method, and different polygons with identifier (coded) represent different soil types.

China's 1:4,000,000 vegetation spatial database-digital vegetation maps was published by State Key Laboratory of Resources & Environmental Information System, Chinese Academy of Sciences in 1996. It was digitized based on China's vegetation map published by Institution of Botany, Chinese Academy of Sciences in 1979. Also Albers Equal Area Conic was used as projection method, and different polygons with identifier (coded) represent different vegetation types.

Spatial analysis

The one-tenth of national population sampling areas digital polygon map (including EC mortality data in its attribute table) and China's digital soil map were loaded into Arc/Info 9.0 as different layers. Soil types of each county can be obtained by overlay analysis (one method of spatial analyses) using these two digital map layers. After we got the soil type codes of each area, we could inquire about the coding table and translate them to true soil types. The 237 sampling areas were divided into 4 death ranks according to their male EC mortality, and soil types of each EC death rank could be listed by summing-up and classifying.

Vegetation types of each county could be obtained by the same method. We also could get vegetation types of the 4 EC death ranks by summing-up and classifying. Therefore, we could compare the soil and vegetation characteristics of the high- and low-risk areas of EC.

Calculation of SOCD

After we got the soil and vegetation types of the study areas, we could calculate the soil organic carbon storage at depths of 100cm and 20cm of each county, using the area size and SOCD value of each type of soil (Yu et al., 2005). Then mean SOCD of each study area could be calculated using the formula as follows:

$$\bar{d} = \frac{d_1 \leftrightarrow a_1}{a}$$

($_1$=1, 2, 3, … n), where $\bar{d}$ is mean SOCD of each study area, d_1 is SOCD of a certain soil type, a is the acreage which this type of soil accounts for, *and* a_1 is the whole acreage of the study area. All these calculations were performed by function programming in the Microsoft Excel software.

Table 1. The Soil Types* of Different EC Death Ranks (male) in Mainland China

EC mortality (1/10^5)	County number	Main soil types
0.61~	47	chernozem, mellow black earth, dark meadow soil, yellow earth, red earth, southern paddy soil, limestone soil, latosolic red soil, yellow-brown earth, brown earth, mountain meadow soil
5.00~ earth,bleached	112	huanggang soil, huangyan soil, oasis soil, latosol, latosolic red soil, yellow podzolic soil, castanozem, bog soil, limestone soil, mountain meadow soil, mountain shrub steppe soil, felty soil, southern paddy soil, northern paddy soil
20.00~ yellowbrown	67	cinnamon soil, tidal soil, huanglu soil, red earth, purplish soil, yellow earth, earth, brown earth, tidal soil, purplish soil, takyr, solonchak, southern paddy soil
80.00~159.29 soil,yellow	11	cinnamon soil, tidal soil, mian soil, huanglu soil, purplish soil, shanxue paddy brown earth, brown earth, red earth

*: Soil types are divided into 57 types according to China's 1:4,000,000 soil spatial database-digital soil map edited by The Institute of Soil Science, Chinese Academy of Sciences

Table 2. The Vegetation Types* of Different EC Death Ranks (Male) in Mainland China

EC mortality ($1/10^5$)	County number	Main vegetation types
0.61 ~	47	1105, 1211, 1213, 1216, 1319, 1320, 1321, 1533, 1640, 2100, 2300, 2400, 2500
5.00~	112	1102, 1105, 1211, 1213, 1216, 1319, 1320,1321, 2100, 2300, 2400, 2500
20.00~	67	1208, 1319, 1320, 2200, 2300, 2400
80.00~159.29	11	1208, 1319, 1320, 1339, 2100, 2200, 2300, 2500

*Vegetation types are coded according to China's 1:4,000,000 vegetation spatial database-digital vegetation map edited by State Key Laboratory of Resources & Environmental Information System, Chinese Academy of Sciences
The codes stand for:1102-temperate evergreen conifers; 1105-subtropical and tropical evergreen conifers; 1208-template and subtropical deciduous broadleaf forests; 1211-subtropical mixed deciduous and evergreen broadleaf forests; 1213-subtropical and tropical evergreen broadleaf forests; 1216-subtropical bamboo groves; 1319-template and subtropical deciduous shrubs and coppices; 1320-subtropical and tropical evergreen and deciduous shrubs and coppices ; 1321-alpine and subalpine evergreen and deciduous shrubs and coppices in the temperate and subtropics; 1339-alpine creeping semi-shrubs in the temperate and subtropics; 1533-temperate steppes; 1640-temperate meadows; 2100-one crop a year and cold resistant cash crops; 2200-two crops a year or three crops two years farming systems and deciduous orchards and economic forests in warm temperate zone; 2300-two crops (upland and paddy) a year farming system and deciduous and evergreen orchards in subtropics; 2400-farming system of one or two crops of rice or three upland crops a year and evergreen economic forests and orchards in subtropics; 2500-double-croppping rice and a warm-loving crop a year and evergreen economic crops and orchards in tropics

Statistical analysis

The fundamental hypothesis in this study is that the spatial variation in SOCD is associated with spatial variation in EC mortality. The relationship between EC mortality and mean SOCD value at depths of 100cm and 20cm of study areas was evaluated by correlation analysis, and all statistical analyses were carried out with SPSS 13.0 (SPSS Inc., Chicago, Illinois, USA). The spearman's rank correlation was used for analysis to observe how strong relationship existed between SOCD and EC in mainland China. The analyses were performed independently for men and women. All the p values were two-tailed and $p<0.05$ was accepted as significant.

Results

Comparison of soil types of high- and low-risk areas of EC.

Through overlay analysis of digital polygon map of EC mortality and China's digital soil map, and by spatial querying, we compared the soil types of the four different death ranks of EC in mainland China. Table 1 shows that the main soil types in the high-risk areas of EC are mostly mian soil, cinnamon soil, huanglu soil, tidal soil and purplish soil, while the main soil types in the low-risk areas of EC are mostly red earth, paddy soil, chernozem, mellow black earth, dark meadow soil, limestone soil and mountain meadow soil. The common soil types that both of the high- and low-risk areas of EC own are yellow earth, brown earth and yellow-brown earth. Through referring to Chinese Soil Genus Records (Vol.1~Vol.6), we could learn that much of the soil of high-risk areas of EC is alkalescent (soil PH>7), while much of that of low-risk areas of EC is faintly acidic or litmusless (soil PH ≤7).

Table 3. Spearman Correlation Between SOCD and EC Mortality, China, 1990-1992

SOCD	EC Mortality (n=237)			
	Male		Female	
	R_s*	p	R_s	p
100cm SOCD	-0.504	0.004	-0.487	0.003
20cm SOCD	-0.575	0.001	-0.526	0.001

* R_s = Spearman correlation coefficient

Comparison of vegetation types of high- and low-risk areas of EC.

Through overlay analysis of digital polygon map of EC mortality and China's digital vegetation map, and by spatial querying, we compared the vegetation types of the four different death ranks of EC (Table 2). From it we could see that the main vegetation types in the high-risk areas of EC were (expressed by coding) 1208, 1319, 1320, 1339, 2100, 2200, 2300, 2500, while the vegetation types in the low-risk areas of EC are 1105, 1211, 1212, 1213, 1216, 1319, 1320, 1321, 1533, 1640, 2100, 2300, 2400, 2500. In the high-risk areas, dry farming and upland crops are the main agriculture of the plowland, most of the mountain forest vegetation are deciduous broadleaf forests, deciduous shrubs and coppices. While in the low-risk areas, rice is the main agriculture, and most of the mountain forest vegetations are mixed forests, evergreen broadleaf forests, bamboo groves, steppes and meadows.

Relationship between SOCD and EC mortality

Relationships between EC mortality of sampling areas in China and SOCD at depths of 100cm, 20cm were evaluated using Spearman correlation analysis in SPSS 13.0 (see Table 3), a negative correlation being found.

Discussion

EC has been reported as the ninth most common malignancy and ranks as the sixth most frequent cause of cancer in the world (Pisani et al., 1993). In addition, EC has a more varied geographical distribution and incidence than any other commonly occurring cancer, which is a reflection of exposure to specific environmental factors (Ghadirian et al., 1992). Ecological environment (such as atmosphere, water, biology and vegetation) and geologic environment (such as soil and mineral) are the physical basement in which human live, so it is important and interesting to study the relationship between soil, vegetation and EC.

By the compare analysis of soil characteristic of high- and low-risk areas of EC, we found that the soil types predominating in high-risk areas were mostly saline-alkali soil, while those predominating in low-risk areas were mostly acidic or neutral. This result seemed to be reasonable, considering the high level of nitrate in saline-alkali areas (Li et al., 2002), which were the sources of nitrosamine, a kind of strong carcinogen(Chung et al., 2003), and the reduced microelement level in human body in saline-alkali soil areas, which was found correlate to EC (Barch, 1989; Nouarie et al., 2004). Saline-alkali soil can prevent plants from absorbing microelement (Tabaksblat, 2002), especially for zinc, selenium ingestion of crops (Demeyer et al., 2001), which lead their reduction in human body. Extensive research in China and South Africa has suggested that N-nitroso compounds and their precursors are probable etiological factors for esophageal cancer in these high incidence areas (Yang et al., 1992). Several nitrosamines, including N-nitrosomethyl benzylamine (NMBA), have been isolated and identified in the diets and gastric juice collected from subjects in Linxian county in Henan province, China. In addition, vegetables and crops can absorb nitrates, nitrites and secondary and tertiary amines, which act as precursors for nitrosamine formation in vivo. Under acidic conditions N-nitroso compounds can be formed in the stomach by reaction of nitrites and amines (Hecht and Stoner, 1996).

Though in most of the areas where soil basicity are high, such as Yangchen (soil PH: 8.0-8.5), northwest of Sichuan province (soil PH: 7.8-8.2) in China, the incidence of EC is high too, there was opposite instance in our study. For example, in Nanao, Guangdong, the soil was acidic (mostly latosolic red soil), while the EC mortality was very high (male: 159.29/105). Since over half of the EC patients in Nanao had a family history of cancers, indicating particular genetic and/or environmental etiological factors affecting this population. The ancestors of most Nanao inhabitants emigrated from the central plains of China, another high EC rate area and the genetic factors could possibly explain at least in part the discrepancy (Su et al., 2007). Moreover, Nanao is an island county isolated from mainland China, where there is particular geographic location and diet habit, and there maybe exist other steady nosogenesis of EC (Ke, 2002; Lin et al., 2005).

Vegetation type is highly correlated with soil type and ambient climate. Chen studied the corresponding relation between the main soil type and main vegetation type in China by using spatial statistics based on Geographic Information System, and the results were accorded with our previous study (Chen, 1999). Vegetations in high-risk areas of EC are mainly deciduous broadleaf forests, deciduous shrubs and coppices, with dry farming and upland crops as the main agriculture. While in the low-risk areas, most of the vegetations are mixed forests, evergreen broadleaf forests, bamboo groves, steppes and meadows, with rice as the main agriculture. So soils in the low-risk areas are often in the reductive environment. Activity of microelement, especially $Fe2+$ and $Mn2+$, is relatively high, as such the effective content of microelement is high too(Czaczyk et al., 1997). Reductive substance can eliminate free radical from human body, therefore preventing DNA from being damaged (Masztalerz et al., 2006; Misiaszek et al., 2004). It is known that DNA damage is one important mechanism of the occurrence of EC (Bonde et al., 2007; Ishii et al., 2006). But up to now it is not yet known how soil and vegetation types affect EC mortality. They maybe take effects by some other indirect ways or factors, such as the validity and absorption of microelement, the formation of some carcinogens, affecting diet and life style.

We also found in this study that SOCD of high-risk areas of EC was lower than that of low-risk areas, which indicated that soil organic matter and soil reduction ability of high-risk areas of EC were relatively low. Soil organic matter composes the important part of soil and was considered as the mark reflecting nutrient storage of soil, because it is the source of all kinds of nutriments needed by crops, and can improve physical and chemical characteristic of soil (Cheng et al., 2004). Soil organic carbon is the result of balance between organic matter entering soil and decomposed process by microorganism. The entering quantities of organic matter are determined in a large scale by ambient climate, landform, moisture state of soil, vegetation and cultivation. Low level of organic carbon in the soil would make against to water-holding capacity, bring about low vegetation fraction and severe water and soil loss, make soil reduction ability decline, lead to low precipitation in these areas(Cheng et al., 2004; Reichstein et al., 2005), which result in a vicious circle of ecologic environment. In this study we have not found the assured mechanism how SOCD affect EC mortality. Certainly, Soil organic carbon couldn’t enter and affect the human body directly, it might only take effects through various indirect ways that have not been found, which should be further explored. For example, on the one hand, low SOCD leads to the deterioration of the soil and ambient climate, resulting in badly surrounding live environment; and on the other hand, soil composition might reflect consequential lifestyle of the local population., e.g., resulting in the decreasing intake of vegetables, fruits and microelements.

In conclusion, soil and vegetation systems are the long-term interaction results of natural and man-made factors, as well as basic ecologic environment in which human live. Due to long term extensive cultivation and immoderate assart under the pressure of large population in China, soil and vegetation systems in many areas have been severely destroyed. This study suggested a relationship between soil type, vegetation type, SOCD and mortality rate of esophageal cancer. The analyses presented here were a bit simple and were intended to present only some of the potential geographic risk factors for EC, but simultaneously generated some research hypotheses on the relationship between geographic factors and EC. We could not get any aetiological association between soil, vegetation types and EC through this study. But we believe it would play an important role in preventing and controlling cancer that we protected ecologic environment, improved soil and vegetation environment in which we are living. In addition, this study was based on nationwide surveys, so the stability of the local population was needed to be taken into account. Demographic differences in the incidence of various cancers are well known and varying incidence in migrant populations point to the important influence of environmental and/or dietary effects in modulating susceptibility (Grover and Martin, 2002). Chinese population was relative stable comparing to western society, especially in the last century, therefore the EC mortality data which came from the one-tenth of nationwide population cause-of-death surveys could represent well the true mortality level. This study also demonstrated that using GIS-based spatial techniques could provide an opportunity to connect diseases with ambient environment, and also lay a foundation to pursue further investigation into the environmental factors responsible for disease risk. But some limitations also exist for this epidemiologic study. First, it was based on secondary public and shared data. Second, we compared EC mortality data in 1990-1992 to soil and vegetation databases set up in 1978 and 1979, respectively, though the soil and vegetation status shouldn't change in less than two decades except for mega disaster. In addition, exposure had to happen many years before the cancer, and a cancer happening in 1990 could have been caused or triggered by an exposure taking place before 1980. Third, we didn't take other known risk factors into account due to the difficulties of nationwide investigation, which might exaggerate the relationships. Therefore, monitoring data and other known or unknown esophageal cancer risk factors should be taken into account in further studies in order to reduce ecological confounding.

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